SENIORS

SAFETY ENHANCED INNOVATIONS FOR OLDER ROAD USERS

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EXECUTIVE SUMMARY

In the coming decades, the share of older persons in the populations of the member states of the European Union (EU) will increase. Due to declining fertility rates and an increase in average life expectancy, the proportion of people of working age in Europe will be shrinking while the number of seniors will be expanding. By 2050, persons 65 years and older will likely account for 28.1% of the total population of EU member states. Seniors today are more mobile than seniors of earlier generations and mobility is critical for the maintenance of life satisfaction and subjective well-being. Therefore, this population aging is associated with an increase in the number of elderly road users. But participation in road traffic also bears the risk of being involved in road accidents. Due to age-related physiological changes the fatal accident risk for elderly road users is higher than that of their younger counterparts.

The main goal of the SENIORS project is to improve the safe mobility of the elderly. For this purpose the deliverable at hand provides an overview of the factors influencing safety and mobility of elderly road users. International projects, national databases on transport, and studies from the field of traffic psychology were drawn on to point out mobility habits of the elderly, their physical limitations as traffic participants, common accident scenarios as well as the behaviour of the elderly as traffic participant.

An in-depth analysis of mobility habits of elderly persons was conducted for the countries Germany, Italy, and Spain. Here, among others the frequency of trips, travelled distances, and trip purposes were analyzed for elderly persons as car occupants, cyclists, and pedestrians and were compared between the three countries to provide insight into the mobility behaviour of senior road users. The motorized individual transport is the most popular way of traffic participation among seniors and the rate of license holders as well as the availability of a car in the own household are high.

Since driving is a complex task that requires continuous information processing and appropriate and timely reactions, a person's ability to move, perceive and react to the environment need to be considered. Throughout a literature research the changes to motor, visual, and cognitive functions that the ageing process brings about were analyzed in the deliverable at hand as well as the contribution of these functions to involvement in car accidents.

Furthermore, drawing on national databases and studies from the field of traffic psychology, typical accident scenarios of elderly road users were depicted as well as their use of safety equipment and their behaviour as car occupants, cyclists, and pedestrians. This synopsis also gives an idea of the availability of data in the field of transport and points out research gaps. At the end of the report, indications for future research efforts as well as for further activities in the SENIORS project were derived.

Contributions of the partners:

FCA	Co-ordination of the deliverable
	Analysis of mobility habits of elderly road users in Italy (Section 3.2); Data analysis and literature review on accidents, use of safety equipment, and behaviour of elderly traffic participants (Section 5)
TRL	Literature review of age-related changes affecting driving performance and possible interventions (Section 4)
BASt	Analysis of mobility habits of elderly road users in Germany (Section 3.1); Data analysis and literature review on accidents, use of safety equipment, and behaviour of elderly traffic participants (Section 5)
IDIADA	Analysis of mobility habits of elderly users in Spain (Sections 3.3 and 3.4); Data analysis and literature review on accidents, use of safety equipment, and behaviour of elderly traffic participants (Section 5)
All	Partners contributed to give an overview on recent scientific literature and European projects

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LIST OF ABBREVIATIONS

CATI	Computer-Assisted Telephone Interviewing)
CIREN	Crash Injury Research and Engineering Network
DGT	Dirección General de Tráfico of Spain
DLR	German national aeronautics and space research centre
EEFM	Enquesta de Mobilitat en un Dia Feiner
ESRA	European Survey of Road User’s Safety Attitudes
EU	European Union
GIDAS	German In-Depth Accident Study
HP	Hazard Perception
infas	Institute for Applied Social Sciences
LogMAR	Logaritm of Minimum Angle of Resolution
SARTRE	Social Attitudes to Road Traffic Risk in Europe
TTA	Time-to-arrival
UFOV	Useful field of view

1. INTRODUCTION

1.1 THE EU PROJECT SENIORS

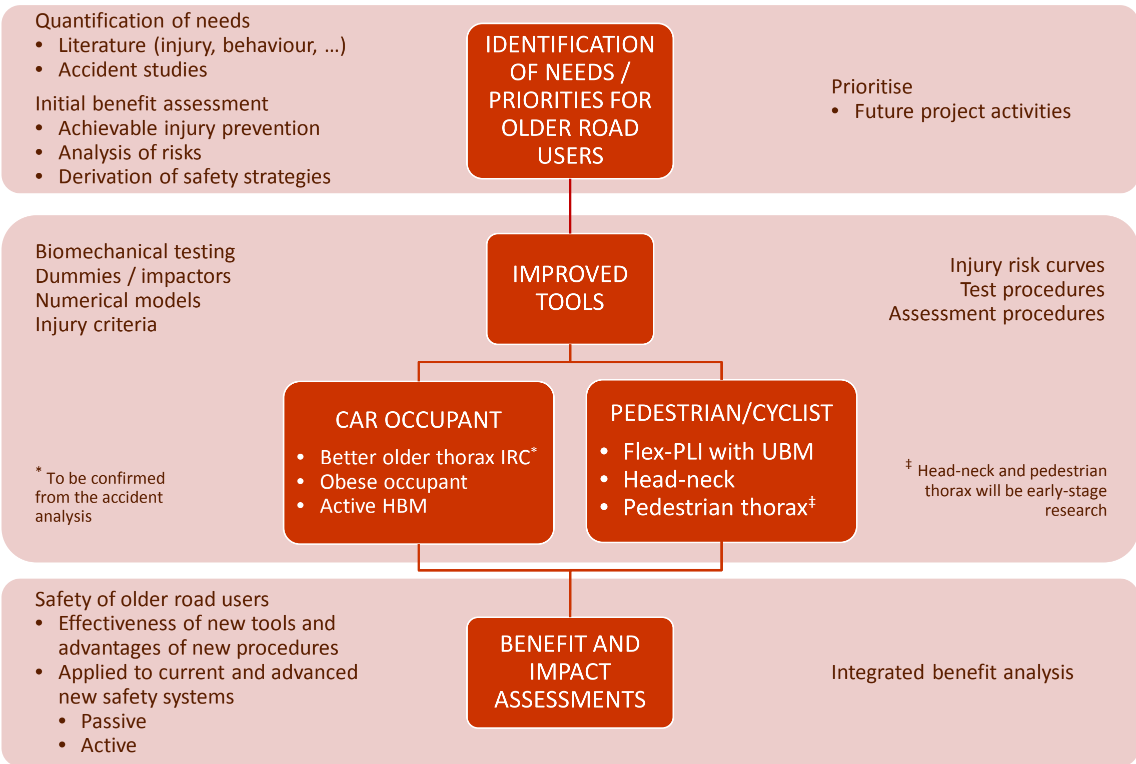
Because society is aging demographically and overweight / obesity is becoming more prevalent, the SENIORS (Safety ENhanced Innovations for Older Road userS) project aims to improve the safe mobility of the elderly, and overweight / obese persons, using an integrated approach that covers the main modes of transport as well as the specific requirements of this vulnerable road user group.

This project primarily investigates and assesses the injury reduction in road traffic crashes that can be achieved through innovative and suitable tools, test and assessment procedures, as well as safety systems in the area of the passive vehicle safety. The goal is to reduce, in near future, the numbers of fatally and seriously injured older road users (and obese persons) for both major groups: car occupants and external road users (pedestrians, cyclists, e-bike riders).

Implemented in a project structure, the SENIORS project consists of four technical Work Packages (WP1 – WP4) which interact and will provide the substantial knowledge needed throughout the project. These WPs are:

WP1: Accidentology and behaviour of elderly in road traffic
WP2: Biomechanics
WP3: Test tool development
WP4: Current protection and impact of new safety systems

In addition, there is one Work Package assigned for the Dissemination and Exploitation (WP5) as well as one Work Package for the Project Management (WP6). The overall scope for the SENIORS project is shown in the flowchart below.



1.2 BACKGROUND FOR THIS DELIVERABLE

SENIORS WP1 is focused on identification of the key starting points in the project and to derive safety strategies for the project work packages. According to this the following topics are under investigation:

- Identification of the most critical accident scenarios and injuries sustained as well as the transport modes that represent a higher risk for the older road user.
- Understanding the characteristics of the most common and critical accidents involving elderly road users.
- Studying of the effect of this different modal split on road safety in order to correlate mobility with fatalities and injuries.

This deliverable aims to improve the knowledge on the mobility habits of the elderly based on literature studies, previous European research projects and new mobility data that includes the main modes of transport. To enable safety measures to cover all aspects related to the elderly it has been adopted a multidisciplinary approach based on demographic trends, mobility habits, physiological and physical aspects, habitual and behavioural differences, that include understanding the most common and critical accidents involving elderly road users.

1.3 OBJECTIVES OF THIS DELIVERABLE

The objectives of this report is to provide a systematically overview over those factors that influence safety and mobility of older road user. According this the investigated topics are the following:

- Acquiring of knowledge about different transport modes (driving, public transport, special transport, walking/cycling) elderly people habits.
- Reviewing information on all human factors that affect older driving performances: age-related changes (psychomotor and motor decline, visual decline), cognitive decline (visual attention and speed of processing), exploring crash risk and its relation to age decline.
- Focusing on elderly persons' behaviour in a car and behaviour as pedestrian/ cyclist with more emphasis on accident data, in order to identify typical road safety-relevant characteristics of older road users in comparison with younger road user groups.

To cover all issues of older road users about mobility and behaviour an exhaustive analysis of previous research projects and literature studies has been done in advance.

1.4 STRUCTURE OF THIS DELIVERABLE

Section 2 of this report deals with demographic trends and provides an overview on recent scientific literature and European projects.

Section 3 of this report concerns the mobility habits of elderly people. Data refer to three European countries: Germany, Italy and Spain. Data include information on the modal split to identify the preferred transport modes of the elderly and to weigh the risk of injury based on exposure. Comparison of all available national data sets between the partner country samples allows a description of the current mobility patterns of older road users as well as an assessment of different factors influencing respective needs and problems.

Section 4 of this report focuses on how age-related changes affect driving performance and on possible interventions.

Section 5 of this report provides an overview of the travel behaviour and the road safety situation of elderly road users (car drivers, car passengers, cyclists, and pedestrians) in order to understand their behavior as road users involved in car accidents. Data refer mainly to three European countries (Germany, Italy and Spain) and US.

The conclusions of the work are shown in Section 6.

2. THE ELDERLY ISSUE

European countries face great challenges because the demographic structure in the EU is changing rapidly, due to reducing birth rates and increasing life expectancies. The aging population has a variety of implications for society, and the quality of life of the older persons is an important issue.

Recent evidence (European Commission, 2015 a) also suggests that today's elderly (65 years and older) population is healthier, more affluent and more mobile than earlier generations of elderly people, thus producing greater demand for social and leisure activities. It is evident how quality of life in old age is linked to mobility needs; indeed. For social integration it is relevant to ensure to the elderly road users freedom of movements, this is essential to the maintenance of life satisfaction and subjective well-being because it allows one to readily meet other life needs. Maintaining a driver's license is an important issue of independence nowadays both for males and females.

Europe is experiencing a demographic change which leads to the fact that more elderly people will take part in the road traffic using different transport modes. As a consequence thereof and due to the vulnerability of the elderly the crash occurrence and the injury patterns will change and effects will even increase in the upcoming years. This challenge must be addressed by improving the protection level of this important group of road users (vehicle occupants as well as pedestrians and cyclists).

In this chapter demographic trends and an overview of recent scientific literature and European projects are described in order to provide relevant information regarding elderly; when possible a distinction between younger elderly (65-74 years) and the older elderly (≥ 75 years) has been made.

2.1 CONSEQUENCES OF THE DEMOGRAPHIC CHANGE

In the coming decades, the share of older persons in the populations of the member states of the European Union (EU) will increase (European Commission, 2015 a). Demographic trends also mean that the proportion of workers supporting those in retirement will halve from an average of four today, to just two, by 2060. The 2015 Ageing Report (European Commission, 2015a) sheds light on the economic, budgetary and societal challenges that policy makers will have to face in the future as a result of these trends. The report's long-term projections provide an indication of the timing and scale of challenges that can be expected so as to inform European policy makers about the scale and timing of the challenges they must face.

The current demographic situation in the EU-28 is characterised by continuing population growth. In 2014, the population of the EU-28 was shifted as follows: young people (0 to 14 years old) made up 15.6% of the EU-28's population, while persons considered to be of working age (15 to 64 years old) accounted for 65.8% of the population. Older persons (aged 65 or over) had an 18.5% share (an increase of 0.3% compared with the previous year). Across the EU Member States, the highest share of young people in the total population in 2014 was observed in Ireland (22.0%), while the lowest share was recorded in Germany (13.1%). Regarding the share of persons aged 65 or older in the total population, Italy (21.4%) and Germany (20.8%) had the highest proportion, while Ireland had the lowest proportion (12.6%) (Eurostat, 2015 a).

The demographic old-age dependency ratio (people aged 65 or above relative to those aged 15-64) is projected to increase from 27.8% to 50.1% in the EU as a whole over the projection period. This implies that the EU would move from having four working-age people for every person aged over 65 years to about two.

On January 1st, 2015 the population of the EU-28 was estimated at 508.2 million, 1.3 million more than the year before and it is expected a significant shift in the age distributions of populations (Eurostat, 2015 b). In particular according to an European study (European Commission, 2015 a) these demographic changes are expected to have a major impact on labour market developments (see Figure 2.1) because of an increase of the pensionable age. For this it is reasonable to expect that seniors could continue to work and to use specific means of transport.

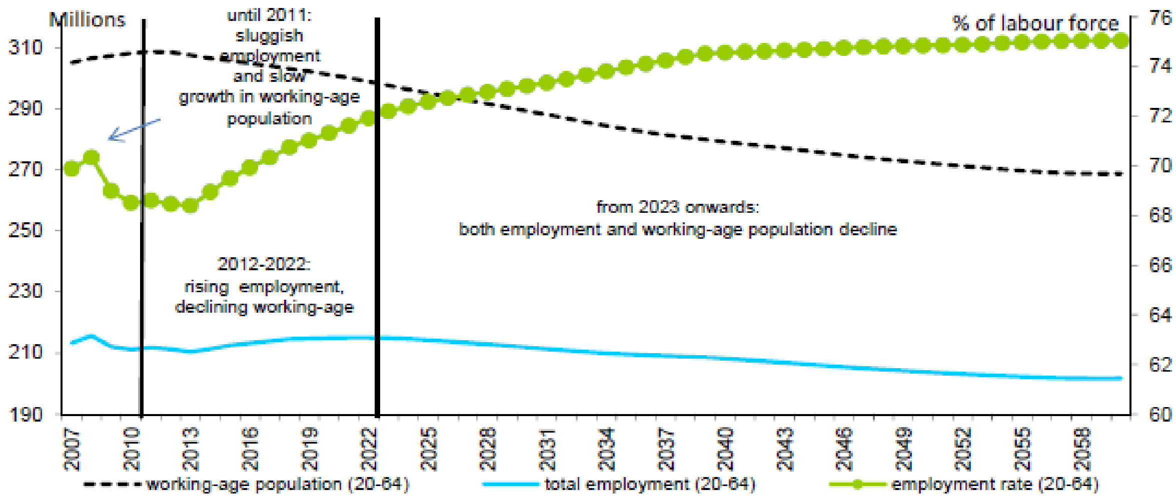
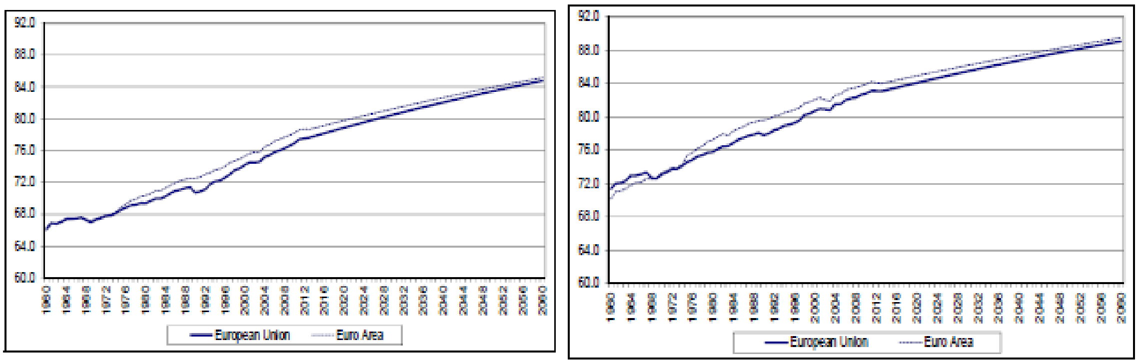


Figure 2.1 Population and employment developments

The number of elderly people is expected to increase with a total of 10% in the EU-28 by 2050. The expected increase in the number of elderly is different for the younger elderly (65-74 years) and the older elderly (≥ 75 years). Exactly the older elderly will increase of 7% by 2050 in almost all European Member States, while the younger elderly will increase of 3% by 2050. This demographic change can be explained by three main factors: 1) increased longevity, 2) declined fertility over many years and 3) migration. This increase in the older population coincides with an increase in older road users since far more elderly people will actively participate in traffic.

In the EU (European Commission, 2015 a), life expectancy at birth for males is expected to increase by 7.1 years over the projection period, from 77.6 years in 2013 to 84.7 years in 2060. For females, life expectancy at birth is projected to increase by 6.0 years for females, from 83.1 in 2013 to 89.1 in 2060 (see Figure 2.2).

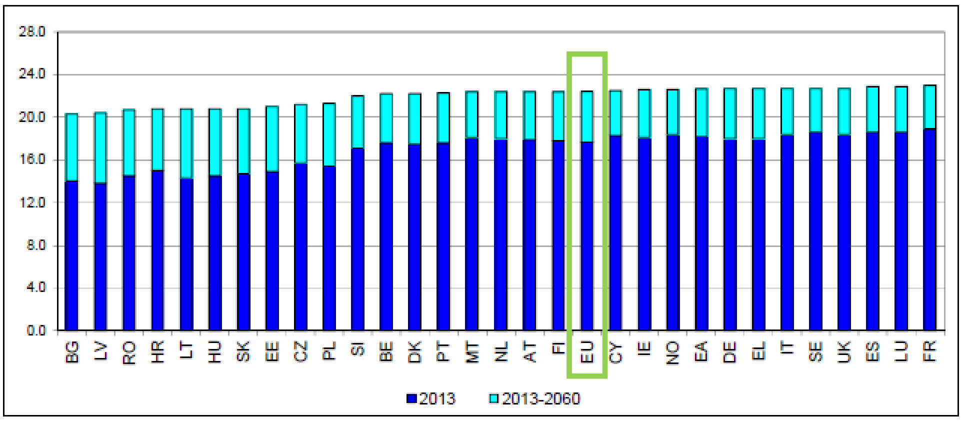


a) b)

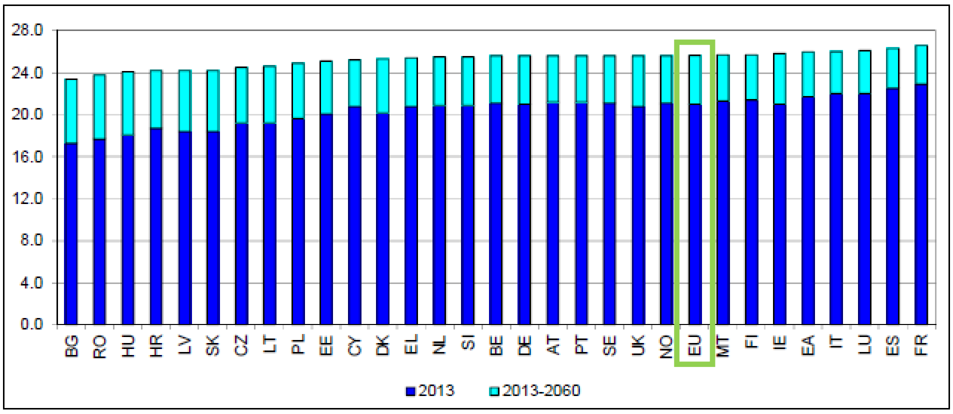
Figure 2.2 Life expectancy at birth (in years): a) men; b) women

In particular an European study (European Commission, 2015 a), reported in Figure 2.3, shows that overall in the middle west European countries, in 2060 life expectancy at age 65 for males will reach about 23 years, meaning that life expectancy is about 88 years old, and it is slightly higher than the European average (84 years old).

This trend is different according to gender: for women life expectancy at age 65, in 2060, is very similar in countries like Italy and Spain (about 91 years old) and higher than the European average; while in countries like Germany and United Kingdom life expectancy at age 65 is very similar to the European average (about 90 years old).



a)



b)

Figure 2.3 Projection of life expectancy at 65 (in years): a) men; b) women

The elderly face many challenges in trying to stay mobile and active in society. As a result, the road safety situation of the elderly will also change since the normal ageing process makes people more prone to experience functional declines that can make driving a car more difficult. However, the fatal accident risk for elderly cyclists and pedestrians is many times higher than for elderly car drivers. As a consequence, while at the moment one road traffic fatality out of five is aged 65 or over in Europe, it is expected that by 2050 one road traffic fatality out of three will be an older person which is an increase of 13%. Therefore, the challenge lies in making the European traffic safety policy and the transportation system 'silver proof'. The risk factor analysis, indeed, revealed that the elderly accounted for 25% of all traffic fatalities in 2013 in the EU (Polders et al., 2015).

The demographic change is reflected in the population of road users. In fact, today's older road users are driving more often and driving longer distances than previous cohort. Furthermore, in the United States Kent, Funk and Crandall (2003) foresaw 50,000 additional serious injuries between 1966 and 2012 only due to this demographic change. Although in the future the older drivers will be more vital and experienced, the increase of people aged 75 and above, the increase of license rates for older drivers and the increase on the mobility for these drivers will lead to a further increase of fatalities among older drivers.

In addition it is expected that elderly people will continue to take part in traffic by walking (as pedestrians) or cycling (as cyclists); in particular, electrical assisted bicycles (e-bikes) are becoming particularly popular among elderly people because they can easily join in on enjoyable bike trips and don't have to rely on the help of others. As the first experimental data have shown (Vlakvelda et al., 2015) elderly rides faster on an e-bike than on a normal bike and this could be another relevant risk factor to take in account.

In many aspects the age of road users is one of the most differentiating factors when analysing accident data. Ageing has an important influence on physical ability and frailty making elders one of the most vulnerable road user groups in any mean of transport.

2.2 RESEARCHES INVOLVING THE ELDERLY

The increasing share of older road users in the European population produces considerable challenges for future transportation systems. Older road users are usually regarded as a group with particular limitations and needs; hence great importance has been attached to the consideration of specific requirements of this growing group in transportation research (Millonig et al., 2012). The European project “Growing Older, staying mobile: Transport needs for an ageing society (GOAL)” aims at comprising current knowledge and identifying research gaps in order to develop an action plan for innovative solutions to fulfil the transport needs of an ageing society (Millonig et al., 2012). Actually as the authors remark the **group of older road users is extremely heterogeneous, only joined by their age**. In order to evaluate efficiently whether current research and development activities are appropriate for fulfilling the differing needs of older road users with dissimilar characteristics, it is necessary to comprehensively investigate and categorise the main relevant determinants of elderly mobility and identify typical combinations of such characteristics.

Mobility among older road users is considered important from the perspective of independence, well-being and quality of life, as a means to reach desired place and out-of-home activities (Spinney, Scott, Newbold, 2009; Ravulaparthy, Yoon, Goulias, 2012). But with rising age, a number of factors exert significant impact on both the mobility behaviour and mobility needs of the elderly. Factors identified as influencing the mobility behaviour of the older road users range from health factors (including a variety of impairments that affect the opportunities to stay mobile autonomously) to life transition points (such as retirement and the change from a multi- to a single-person household) as well as social aspects (such as having friends and family and a consistent and functioning social support network). Other socio-demographic variables, specifically gender, also play a major role in assessing the mobility behaviour of the older age groups (CONSOL, 2013 a; Kim, 2003).

Within the European project “AGed people Integration, mobility, safety and quality of Life Enhancement through driving” (AGILE), Breker et al., 2001, conducted an analysis driving related problems of older drivers, performing interviews and questionnaire surveys with experts and users.

A questionnaire based study was performed in order to capture attitudes and knowledge among experts and users in the field towards ageing drivers and related screening activities. The results showed that a majority of the respondents often met older drivers as a part of their work and rated their knowledge of the issue as rather good. Despite that, most of the respondents were oriented to a safety approach concerning this group and, hence, not up-dated on recent research in the field. Most of the respondents were aware of the importance of car driving to participate in societal events. They were also aware of the fact that older drivers have problems in intersections and that they are more often involved in accidents than other drivers.

To get a better picture of the situation drivers’ face in later, 473 older drivers were involved in a questionnaire based study. Different were the investigated topics: driving habits, accident history, opinions towards training and ageing-related retesting of driving skills, physical mobility, medical diagnoses, attention problems). The results showed: a) importance of using the car for mobility in later life periods; b) physical mobility decreasing in the older age groups (persons over 54 years old reports leg, neck or shoulder problems; **persons over 74 years old report at least one impaired mobility function**); c) prevalence of diseases and problems potentially having negative effects on driving skills.

In the SAMERU project the use of mobility scooter among older people was pointed out (Goss, 2013). Mobility scooter users generally travel up to a mile and sometimes more. The majority of users have owned their mobility scooters for five years or more, and they use it regularly, either two or three times a week or every day. The most popular time for using a scooter is in the morning. Baskets and mirrors are the most popular accessories for the scooters. Over half the accidents (57%) were caused by a car or other vehicle (car doors opening over the pavement and a car turning right); the remaining ones were caused by the mobility scooter.

2.2.1 Fatality rates

The fatality rate (road traffic casualties per year, per million inhabitants) is notably higher than average for older adults: +25% for the age group 65-74 and even +75% for the age group 75-84. The fatality rate per kilometre for drivers aged over 75 years is more than five times higher than the average. Drivers over 85 years old have almost the same risk of collision as those younger than 20 years of age per kilometre driven. In terms of collisions per mile, those older than 85 years are the second most vulnerable group after those under 20 years. When older road users are involved in a collision, the risk of serious or fatal injury is higher due to the increase in frailty with age (Goss, 2012).

In 2014 a total of 25,900 fatalities were registered on the European roads; the elderly (65+) made up 39% of all pedestrian fatalities, 40% of all cyclist fatalities and the 18% and 19% of all car driver and passenger fatalities respectively. The primary cause of this higher fatality rate is the increased fragility of the elderly. The fact that older road users for short trips prefer unprotected modes (bike or on foot) increases their risk of being seriously injured or killed in an accident (Polders et al., 2015; Muller et al., 2014; Martensen, 2015). With reference to pedestrian fatalities Eisses (2011) showed that older adults (65+) have a disproportionate weight, accounting for almost 36% in 2009. The pedestrian fatality rate strongly increases at higher age: from a small increase in the age group 65-69 to twice this value for ages 75-79. The main cause of this higher fatality share is the higher physical vulnerability of the elderly.

2.2.2 Gender influence on elderly mobility

Gender is another significant factor, with regard to mobility behaviour and attitudes towards certain modes of transportation that affects the elderly safety (CIVITAS 2020). It has been observed that the share of women as victims is higher than among other road user fatalities, elderly women are particularly at risk. Chai, Shi, Wong, Er, and Gwee (2016) have seen that men have better cognitive skills than women at detecting hazardous situations, especially as pedestrians.

Vance, Buchheim and Brockfeld (2004) focused on gender disparities regarding access to cars and the impact of other determinants on these disparities. The authors examined survey diaries in order to identify whether women have more constrained access to cars than men and if so how this is mitigated/exacerbated by other determinants (e.g. community design, socioeconomic circumstances, etc.). They used a probit choice model of the determinants of car utilisation on weekdays and it was found that women tend to use the car less, a decision that is influenced by other socio-demographic and activity based determinants. One of these variables is age, indeed the gender differences became even more pronounced with age.

Women show less dependency on the car and rely more on walking and public transport. Men show a higher level of dependency on the car as a mode of transport, which also causes different problems for men and women. Women are more often talked out of driving by their spouses or other people to drive a car and therefore develop different attitudes to their own ability to drive a vehicle. On the other hand men, when they decide or are forced to cease driving, are more likely to be adversely affected by this transformation and adjust their lifestyle to other forms of transport mainly public transport and walking (CONSOL, 2013 a).

Giesel & Rahn (2012) conducted a gender-related analysis of mobility and social participation of the elderly in Berlin and its hinterland. Researchers found out that older women travel the shortest distances and make the least number of trips in total. Additionally, the majority of their trips are made on foot. Men travel less frequently on foot but they cycle more. Women activities are thus concentrated to a large extent on the local residential area, in particular when there is no car available; so older women have to organize their everyday life often on their own. The dissatisfaction is first of all based on missing public transport, leisure, service and shopping opportunities. In this way, older women especially are disadvantaged in these environments. So their social participation could be at risk.

Classen, Shechtman, Joo, Awadzi, and Lanford (2009) have shown that rates for motor vehicle-related crashes are twice as high for older men as for older women, but the proportion of fatalities is higher for older women. To better understand driving errors made in crashes and to suggest prevention strategies, the authors (a) classified violations underlying crashes into errors made during on-road assessments; (b) quantified age, gender, and types of driving errors as predictors of post-crash injury; and (c) examined whether different violations and driving errors occur in different age cohorts (≤75 and > 75 years). The findings have shown that, compared with older male drivers, **older female drivers are at a greater risk for injuries from crash-related violations and driving errors**. This finding holds true when younger and older female drivers are compared with their age cohorts. Injury prevention strategies on the person, vehicle, and environmental levels must receive serious consideration and be tested empirically for effectiveness.

2.2.3 Elderly drivers and compensation strategies

Accident analysis from several databases (Breker et al., 2001) has shown that elderly drivers' accidents more often occur in daylight, on weekdays and on roads that are not affected by snow or ice compared to other drivers. Accidents reflect exposure: elderly prefer driving during the day and in good weather conditions, in order to reduce the risk on the road due their physical limitations. There are several kinds of behaviour among elderly drivers giving a positive effect on traffic safety that this review revealed such as the lower use of alcohol when driving, the **more frequent use of restraints** and signs of not losing the control over the vehicle in curves and straight sections. Moreover older drivers seem to be involved in accidents in which traffic signs had to be read and followed.

Crash data showing age-related increases in crash risk is still evident in many countries around the world (OECD, 2001). Research has shown that older drivers are at an increased risk of being involved in a collision, particularly at intersections, a situation where fast processing of information and quick reactions is needed (Clarke, Ward, Truman, Bartle, 2009; Clarke, Ward, Bartle, Truman, 2010; Mayhew, Simpson, Ferguson, 2006; Koppel, Bohensky, Langford, Taranto, 2011).

Some governments have instated restrictions to driving in order to minimize the risk posed by declines in the skills central to performing the driving task. Although the type and severity of restrictions vary from country to country, these generally involve a combination of medical and/or eyesight checks, self-declarations of fitness to drive, and/or periodic licensing renewal after reaching a certain age (Siren et al., 2013). Although research has shown that cognitive decline can be evident from the age of 50, many individuals can maintain optimal levels of cognitive performance until much later on in life (Dennis & Cabeza, 2008; Janke, 1994). This is one potential reason why licence renewal procedures and medical examination approaches to older drivers do not seem to have any impact on the overall road safety of drivers aged over 65 (Mitchell, 2008).

One of the key elements often discussed within the literature is that elderly drivers are known to compensate for their driving limitations (Donorfio, D'Ambrosio, Coughlin, Mohyde, 2008; Lang, Parkes, Fernandez-Medina, 2013). They often self-regulate their driving by avoiding certain situations. According to national and international studies on the driving characteristics of the elderly, their driving can be described in the following way: a) seniors drive less often and drive shorter distances than their younger counterparts; b) they drive less frequently during rush hours and on freeways; c) they furthermore avoid driving under bad weather conditions and driving at night time (Baldock, Mathias, McLean, Berndet, 2006; Ball et al., 1998; Hakamies-Blomqvist, 1994; Hennessy, 1995; infas & DLR, 2010).

Elderly drivers furthermore drive slower and with a larger headway than younger drivers (Andrews & Westerman, 2012; Nishida, 1999), a behaviour that can be ascribed to the tactical level of vehicle control. This level comprises all driving manoeuvres based on knowledge about oneself, the vehicle, and expectations with respect to future traffic situations that aim at keeping the risk of experiencing a hazard low while participating in traffic. These changes in the driving behaviour of the elderly mostly take place on the strategic and tactical level since decisions here can be made under relatively low time pressure and a division of attention is required less frequently. Generally, it seems that senior drivers try to compensate for their performance deficits mainly by avoiding unfavourable times and situations when travelling as well as by driving cautiously (Weinand, 1997). But it also needs to be noted that this avoidance of risky situations as well as the change in driving style might arise from changes in lifestyle habits, motives, and trip purposes at an advanced age due to changes with respect to employment status and/or place of residence and might not necessarily be manifestations of conscious or unconscious efforts to counteract existing deficits (Jansen et al., 2001).

Clearly compensation isn’t always enough, and drivers may not always be aware of their current limitations. Others may underestimate their ability and stop driving too soon (Stutts, Wilkins, Reinfurt, Rodgman, Van Heusen-Causey, 2001). This is problematic as there is increasing evidence that driving cessation can have negative effects on health and well-being, because it can be related to health deterioration, depression, and even mortality in elderly adults (Edwards, Perkins, Ross, Reynolds, 2009). Similarly, some data have shown that driving cessation can encourage elderly drivers to move to modes of transport that carry greater potential risks of injury (such as walking) thus increasing the risk to their safety and mobility (Lang et al., 2013).

2.2.4 Virtual reality & elderly researches

Nowadays, virtual reality is a great support for elderly researches.

Virtual reality allows to assess the effectiveness of the existing test tools and to develop a basis for new developments of or further modifications to existing dummies or impactors. The expected dynamic performance of humans in impact events, indeed, can be reviewed in order to build on existing knowledge to identify traits and performance requirements that are specific to older occupants.

In the SAMERU project (Goss, 2013), different virtual scenarios have been developed and validated in order to reproduce difficulties that the elderly road users (car drivers, pedestrians and cyclists) meet in everyday life. It is suggested to have health checks for drivers over the age of 65. Indeed, driver training has proven very useful, affording people with the necessary training to help them remain mobile and safer, despite increasing physical or cognitive limitations. For pedestrian it is proposed the need for an improved pedestrian environment that include better maintained surfaces, longer crossing times at pedestrian crossings and better control of cyclists on pavements. Cycle training has provided an opportunity for people new to cycling, or just needing more confidence, to learn how to cycle safely on the roads by using techniques specifically designed for the older cyclist who may not be as flexible (Goss, 2013).

In addition for in-vehicle road test in SAMERU project has been proposed the GERT suit (GERiatric Test suit) to consider the physical elderly limitation (Goss, 2013). The suit simulates the following key items:

- The yellow goggles change your vision blurring eyesight, making it hard to distinguish colours and by narrowing the visual field;
- The headphones reduce high frequency hearing;
- The bandages round knees, elbows and other joints restrict mobility;
- Weights on feet and arms make it more difficult to move round and add the sensation of the loss of strength;
- Gloves simulate the difficulty in gripping things and can also simulate the tremor in the hands;
- The collar round the neck helps simulate how difficult it is to turn your neck;
- Suit also reduces the ability to co-ordinate.

3. Mobility Habits

Mobility means having transport services going where and when one wants to travel; being informed about the services; knowing how to use them; being able to use them; and having the means to pay for them. From this it is usual the usage of “moving population” meaning people who have at least one movement during a working day.

Data analysis provides a comparative picture of the mobility situation of the ageing population in some European countries. Naturally the comparison cannot be based on comparison of means and other exact measurements. However, more general trends, if in line with the stated theoretical considerations and supported by those, are compared. In this regard only descriptive analyses are feasible.

This chapter provides an overview of the mobility habits of elderly people. Detailed data refer to three European countries: Germany, Italy and Spain.

Every partner contributes by data and respective data analysis specifically available to them, therefore broadening the scope of the comparative data analysis in view of a more in-depth assessment of specific factors which may influence the mobility behaviour and needs of the ageing population. Mobility behaviour (long-distance trips, short-distance trips, etc.) is represented by the following variables:

- trip frequencies
- mode of transport
- trip purpose
- travel distance
- travel time

3.1 Mobility in Germany

In 2002 and 2008, within the project Mobility in Germany (infas & DLR, 2010), surveys were conducted in German households to investigate the daily mobility behaviour of the population. Within this study, the proportion of people who leave their house at least once on a given day as well as the number of journeys they travel on a day constitute key parameters in describing mobility. In 2008, 89.7% of all respondents reported that they had left their house at least once on the day of the survey and that they had travelled on average 3.8 journeys.

Compared to 2002, these numbers have risen by 4% and 0.1, respectively. But this increase was not evenly distributed across all age groups. The increase in the proportion of seniors who are mobile was greater than that of younger people. Furthermore, a decrease in the average number of daily journeys was evident for people under the age of 18 years while the number of journeys especially increased for people 65 years and older. In terms of numbers, 81.3% of all respondents over 65 years stated that they had left their house at least once on the day of the survey. On average every mobile elderly person had travelled 3.5 journeys on that day (see Figure 3.1).

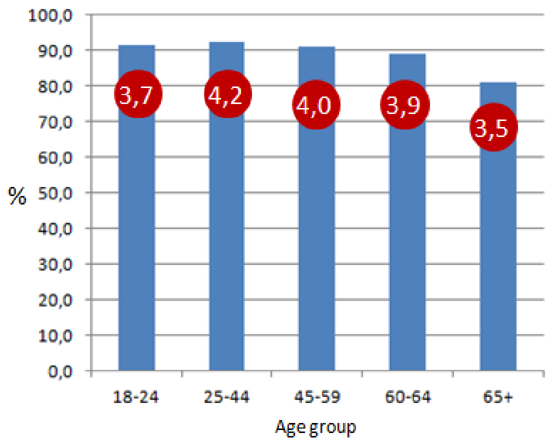


Figure 3.1 Mobility rate and average number of daily journeys per age groups

With respect to transport performance, from 2002 to 2008, an increase in the average number of daily travelled kilometres was observed in all age groups. In the survey in 2008, a person stated to have travelled on average 39.1 km on a given day. Respondents over 65 years reported an average sum of 22.7 km a day (infas & DLR, 2010). Figure 3.2 shows the average number of kilometres travelled on a given day per age group.

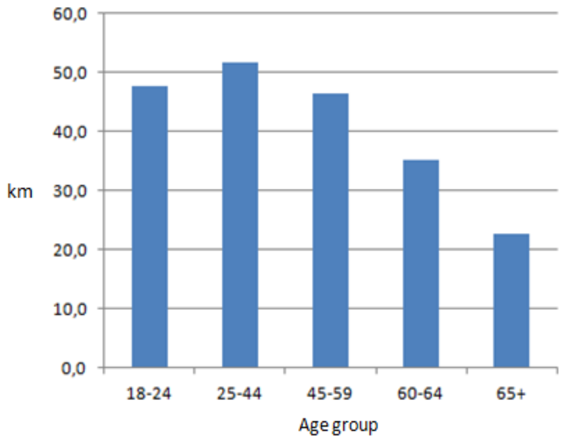


Figure 3.2 Average number of daily travelled km per person of certain age group

When asked with respect to travel time, respondents of all age groups stated that they spend on average 78.6 minutes a day travelling. In the age group of persons 65 years and older, the number came to 71.4 minutes. The rates of travel time for the different age groups can be seen in Figure 3.3.

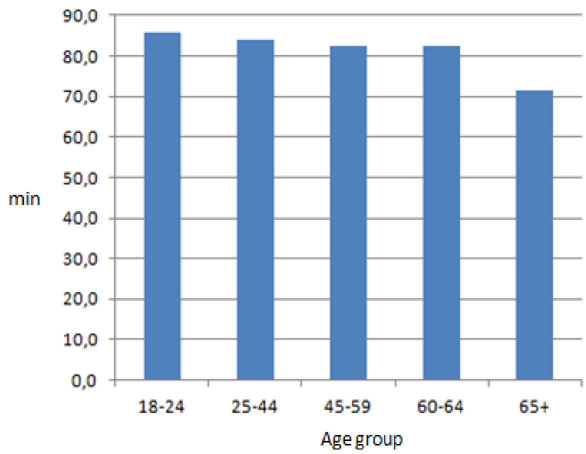


Figure 3.3 Average number of minutes spent travelling on a given day per person of a certain age group

Out of the different kinds of participation in traffic motorized individual transport (i.e., passenger car, motorbike, moped, truck) was the most popular in 2008. It was used for 57.7% of the journeys travelled on a given day by the respondents of the study population. By foot, pedal bike, and public transport 23.8%, 10%, and 8.5% of the journeys were travelled, respectively. Respondents 65 years and older used the motorized individual transport for 48.6% of the journeys a day. By foot, bike, and public transport 34.1%, 9.3%, and 7.9% of the daily journeys were travelled respectively in this age group. Figure 3.4 shows the rates of journeys travelled using the different modes of transport on a given day per age group.

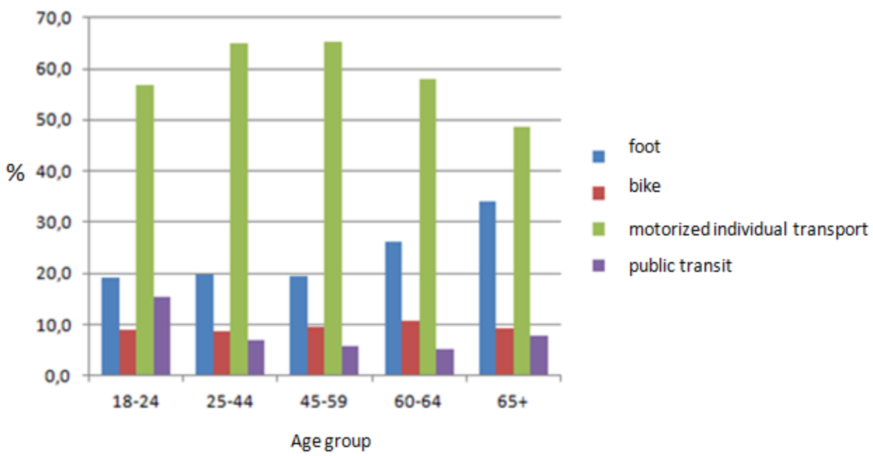


Figure 3.4 Rates of journeys travelled using different transport modes by age group

With respect to transport performance, respondents of all age groups stated that they had used motorized individual transport for on average 78.8% of the travelled kilometres on the day of the survey. They had used public transport, walked, and ridden their pedal bike for 15.5%, 2.9%, and 2.8% of the kilometres, respectively. The proportion of kilometres travelled by motorized individual transport was somewhat lower in the group of seniors. They reported having used it for 70% of the travelled kilometres that day. They had travelled on average 20.4%, 6.3%, and 3.8% of the kilometres that day by public transport, foot, and bike, respectively (infas & DLR, 2010).

Elderly do not seem to combine different modes of transport often. A bike together with the public transport was only used for 0.1% of the journeys of a day. The usage of motorized individual transport together with public transport was indicated for 0.3% of the journeys travelled.

With respect to the purposes of the travelled journeys elderly persons mostly travel for recreational purposes, shopping and personal errands. Trips due to job and education justifiably do not play a vital role.

When elderly people use the motorized individual transport, in 3 out of 4 cases they do so as drivers compared to passengers. Holding a driver's license is considered desirable by many people. In 2008, 87.0% out of all respondents of the Mobility in Germany survey reported to possess one. The proportion of license holders in the age group of people 65 years and older has risen from 65% in the year 2002 to 74.4% in 2008. With respect to gender, 76.4% of the elderly men and 69.7% of the elderly women stated to hold a driver's license in 2008. Here, especially the rate of license holders among women aged 65 to 74 years has risen, from about 50% to about 70% during these six years. The respective rate in the group of men aged 65 to 74 years increased only by about 5%. Having at least one car available in the household was stated by 88.7% of all respondents in the sampled population. In the group of the seniors 76.0% reported the same. Elderly respondents furthermore reported to have travelled on average 10,849 km in the year 2008 by car. In the overall population the car was used to travel on average 14,359 km in a year (infas & DLR, 2010).

It can be concluded that most age groups in Germany have become more mobile during the last years while especially the activities among the elderly have increased. When looking at the course of mobility across age groups though, one can see that the number of persons who leave their house at least once on a given day is lower among the elderly than among other age groups. Furthermore, persons over 65 years of age travel fewer journeys as well as shorter distances a day compared to other age groups. With respect to owning a vehicle, the rate of elderly who stated to have a car available in the household is lower than among younger persons.

The proportion of households with vehicles that were purchased as new cars increases with increasing age of the main income earner. Highest rate of 43% can be found in the group of people between 70 and 79 years old (Federal Statistical Office of Germany, 2011). Elderly persons seem to prefer vehicles that are characterized by a high seating position, large doors, and all-round vision (Johannsen & Müller, 2013 b). In the age group 65 years and older 27.7% stated that they own a large executive car. This proportion is greater than in all other age groups. Only 13% of seniors own a subcompact, which constitutes the smallest proportion in all age groups (infas & DLR, 2010).

Bicycles are available in a large number of German households. In the sampled population of the Mobility in Germany survey in 2008, 78.2 % of all respondents reported owning a pedal bike. Among people 65 years and older the rate came to 61.5 % (infas & DLR, 2010). With respect to the kind of bicycle they own, a recent representative survey in the population of German cyclists showed that 78.2% of all 65 years and older respondents own a city bike. An e-bike/pedelec, a mountain bike and a racing bicycle are owned by 7.0%, 6.1%, and 3.9% of the seniors, respectively (calculations based on data from von Below, 2016). Among the elderly owners of an e-bike/pedelec, 75% stated that they have motor support until 25 km/h; 18% indicated support above 25 km/h. Among all queried seniors, 43.6% stated that they have already ridden an e-bike/pedelec or were at least interested to do so one day. On the other side, 62.4% said that buying such a bicycle is out of the question for them (calculations based on data from von Below, 2016).

3.2 Mobility in Italy

The source of this study is the 2014 AUDIMOB (Observatory based on mobility styles and mobility habits of Italian people) report about mobility styles and mobility habits of the Italian people. The data shown in this chapter are referred to the sample previously defined, in the period from 2000 to 2014. Concerning SENIORS, the age group of interest is Over 65. No other distinction is possible because the telephone interviews cover people until 70 years old.

The study was conducted by using the CATI system (Computer-Assisted Telephone Interviewing) and covers a statistically significant sample of the Italian population aged between 14 and 70. The sample has been classified based on gender, age groups and occupational characteristics and the individual mobility has been measured during the working days.

The overall results let half-view that a change in the mobility habits is taking place in Italy. Italian people restart to go out in the free time (+7.8%) and the moving population reaches 79.7%, regaining almost five percentage points with respect to the minimum registered in 2012 (75.1%). Furthermore, there is an increase of the proximity mobility; indeed the 53.4% of the movements are within a radius which is less than 5 km (45.7% in 2013) and the total length per person in a working day decreases of approximately 5 km. In addition, it seems that Italian people are getting more involved in the use of public transportations, bike and on foot movements with an overall increase of 3.4% to the detriment of the use of private cars.

In 2014 there was a recover of the mobility demand for the overall population, with an increase of 4.3 percentage points as can be seen in Figure 3.5 where the percentage of moving population during a working day out of the overall population is shown. Focusing on the Over 65, it appears that the recovery for this age group is slower than the one of the overall population. Furthermore, the Over 65 minimum was registered in 2004 and it was probably due to the introduction of a new driver's license in the Italian system.

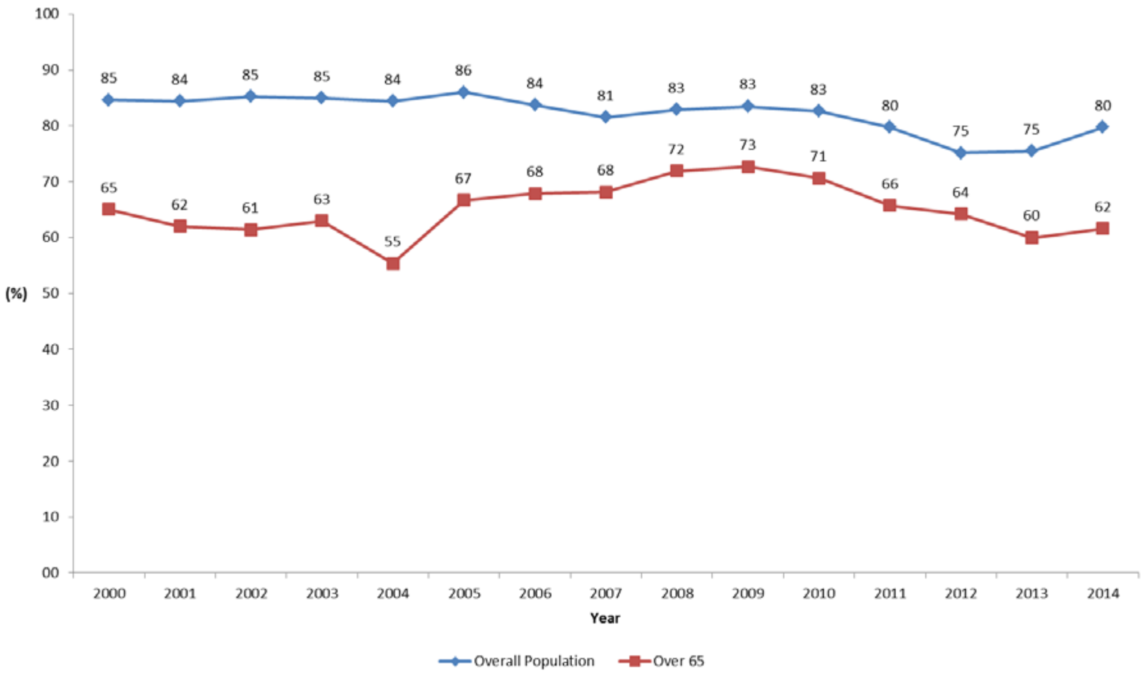


Figure 3.5 Moving population

In particular Figure 3.6 illustrates clearly that the lower percentage of the moving population is associated to the age group 65 and older.

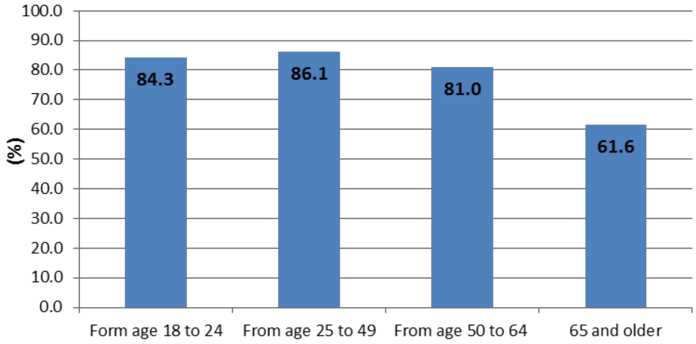


Figure 3.6 Moving population per age groups

As can be seen in Figure 3.7 the high percentage of moving population is among employed people, while housewives and retired leave their house less often. The increase for all the age groups below 65 is between three and five percentage points, whereas for the age group 65+ the grow is slower and the mobility demand increases of 1.6 percentage points.

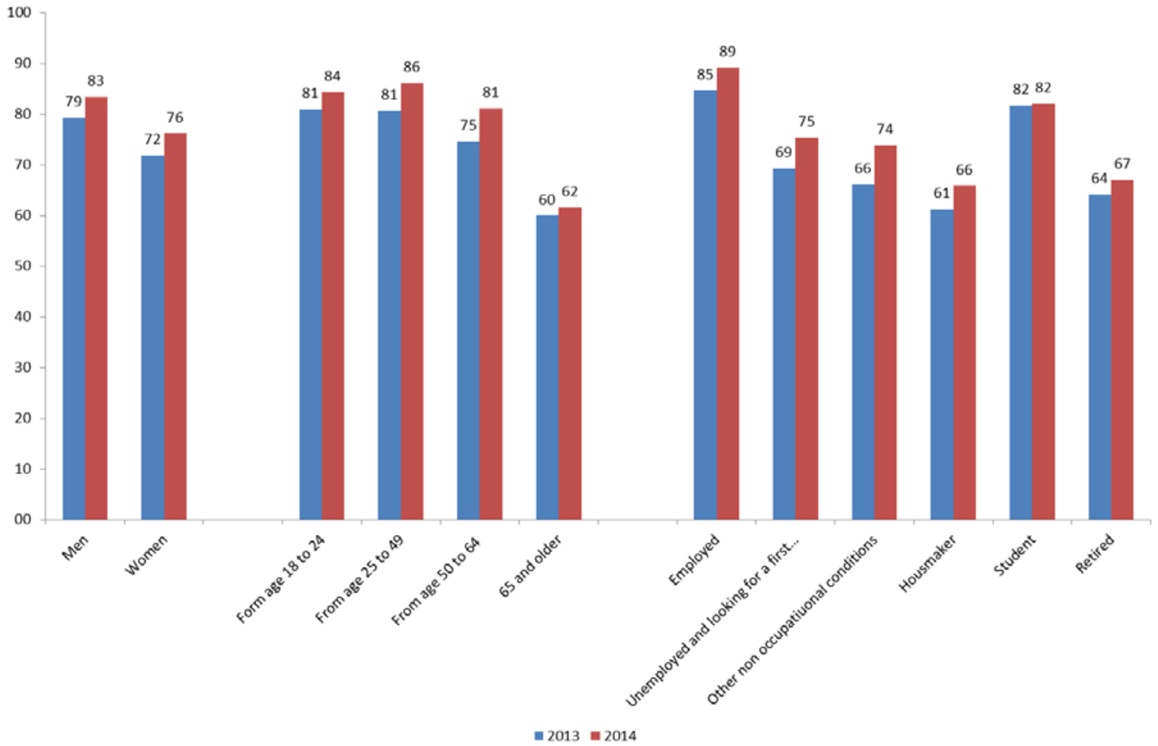


Figure 3.7 Moving population per social-biographical characteristics

Although there is a global increase of the mobility, the average number of daily movements per person remains at a mean value less than three with a slightly increasing trend (see Figure 3.8).

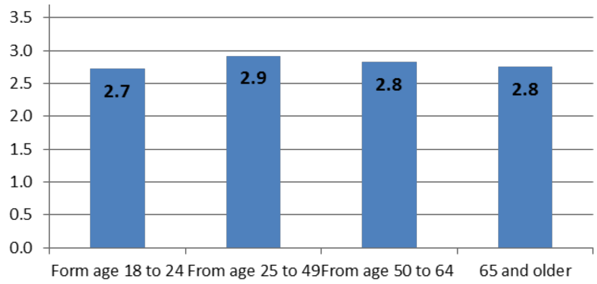


Figure 3.8 Average number of daily movements per age groups

This is also shown in Figure 3.9 where, in addition, it is possible to point out that the elderly trend is practically coincident with the one of the overall population from 2011 to 2014.

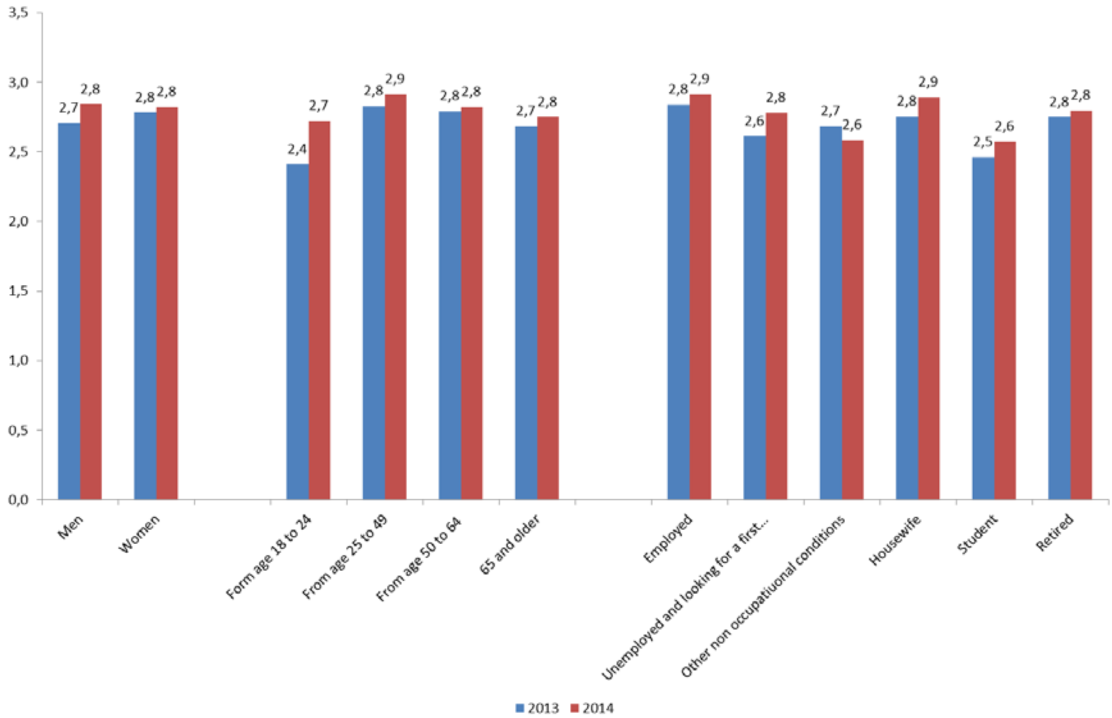


Figure 3.9 Average number of daily movements per person per social-biographical characteristics

Concerning the average time for the daily mobility per person (see Figure 3.10) the minimum value for the elderly is registered in 2004 and except for this value the elderly trend is very close to the one of the overall population. In the last year the time for the daily mobility per older people is about 54.2 minutes (close to the overall population value).

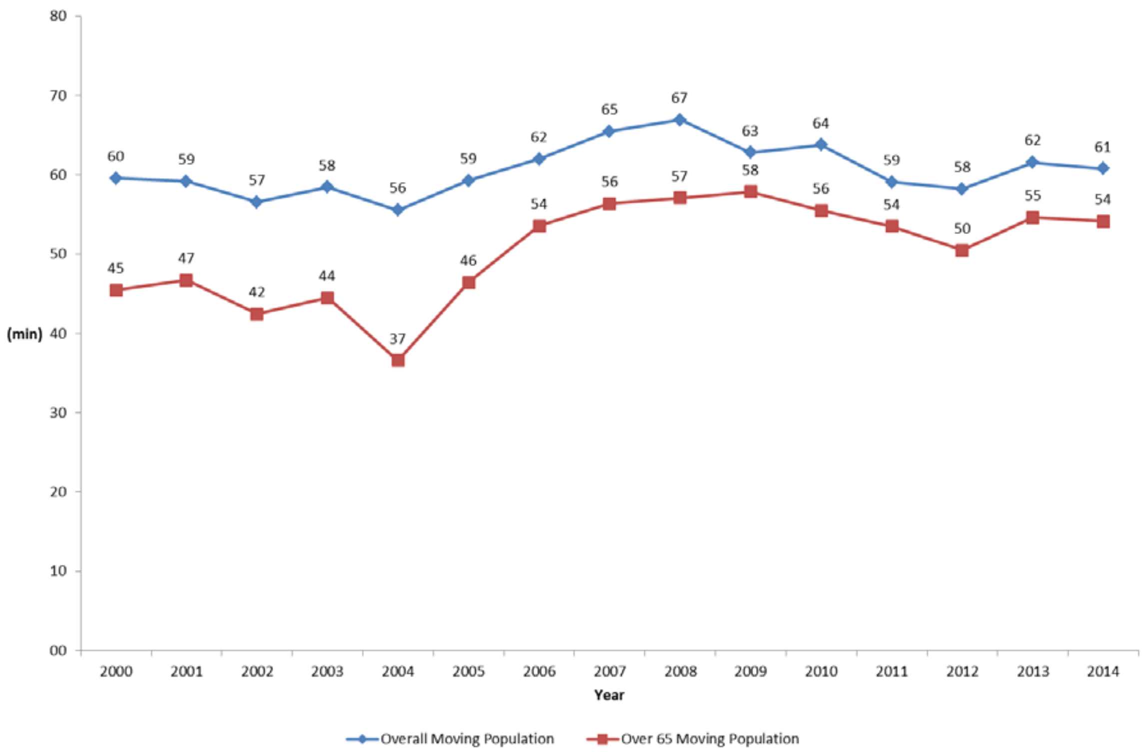


Figure 3.10 Average daily time per person

Considering the classification per social and biographical characteristics the people who spend less time for the daily mobility in 2014 are the housewives (44.67) and the elderly (54.16) with very small change with respect to the data referred to 2013.

Figure 3.11 shows the average daily distance per person. It is possible to point out that there is about 4 km decrease of the average distance per person from 2013 to 2014. This decrease is mainly due to a decrease of the mobility radius: Italian people are moving more frequently but for shorter distances. Furthermore the overall moving population and the elderly trends are very similar with a downward shift of the second one.

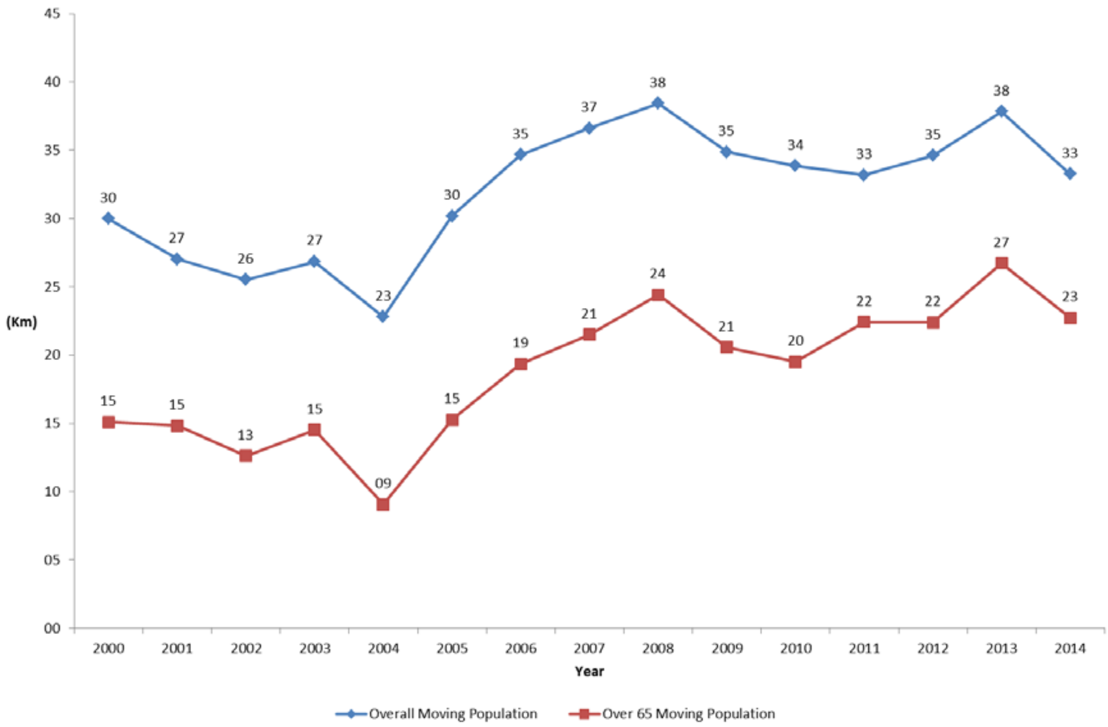


Figure 3.11 Average distance per person

Considering the mobility reasons, Italian data classify mobility reasons in three different classes: free time, family study and occupational reason. Specifically, Figure 3.12 shows how Italian people are restarting to go out in the free time (+7.8%) to the detriment of the movements for family reasons.

Figure 3.12 Mobility reasons

Instead Figure 3.13 shows the mobility reasons in more detail in 2014, indeed, here the Italian population is categorized per age groups. Specifically, there are four classes: from age 18 to 24, 25 to 49, 50 to 64 and 65+. From this figure it is possible to focus on the elderly behaviour noticing an increase of the mobility due to the free time. In 2014, free time and family reasons have almost the same percentage among the Over 65.

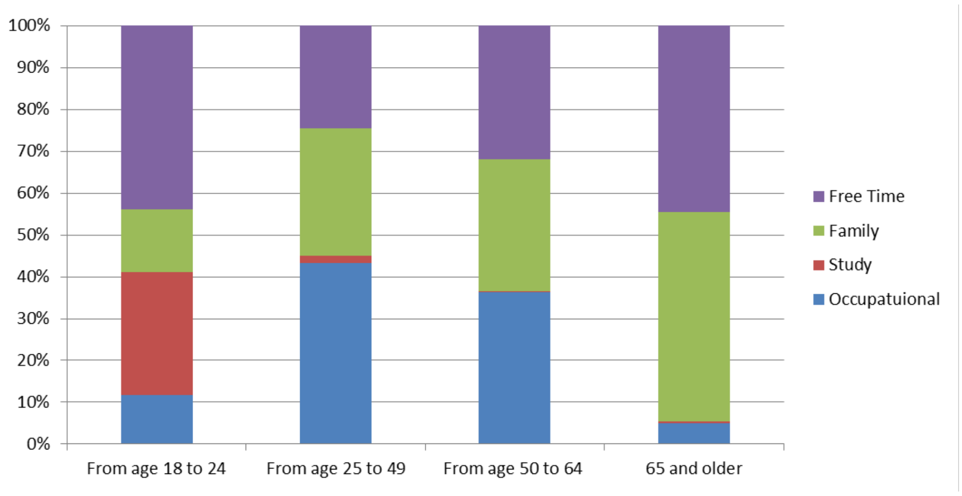


Figure 3.13 Mobility reasons per age groups

Figure 3.14 is related to the Italian population and shows that seniors preferred means of transportation is on foot but the percentage has a small decrease from 2013 to 2014 (from 45% to 41%).

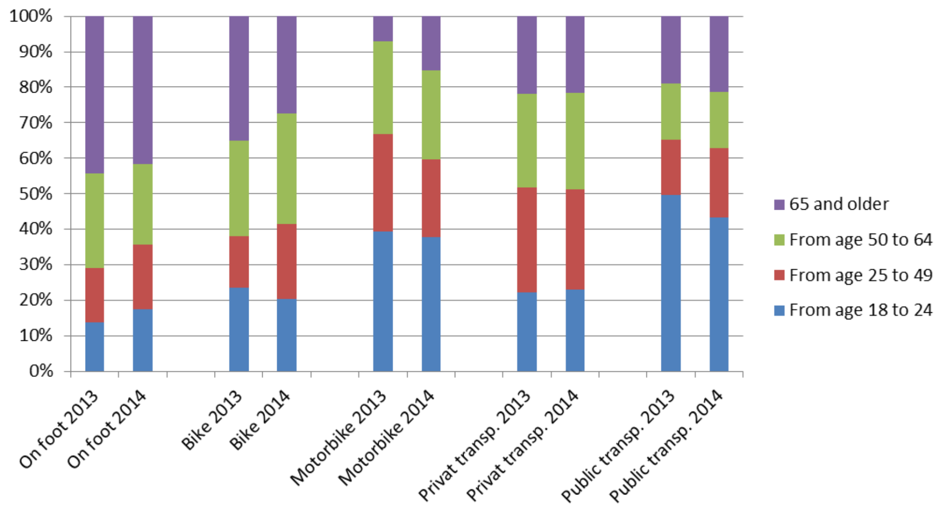


Figure 3.14 Means of transportation per age groups

About the satisfaction for the use of the transportation it appears that, generally, the most satisfying means of transportations are the private transportations which have obtained the highest rates and the private car is in a high position. Less truthful is the result for the elderly level of satisfaction for the use of the motorbike (see Table 3.1).

Table 3.1 Satisfaction for the use of the transportation

Means of transportation	2013				2014			
	From age 18 to 24	From age 25 to 49	From age 50 to 64	Over65	From age 18 to 24	From age 25 to 49	From age 50 to 64	Over65
Motorbike	8.1	8.4	9.1	8.6	8.0	8.4	8.5	8.4
Private car	8.0	8.2	8.0	8.3	8.1	8.2	8.1	8.3
Urban bus	5.5	6.1	6.1	6.7	6.0	5.9	6.2	6.3
Underground	7.2	7.5	7.6	8.2	7.1	7.7	7.7	8.1
Bus	6.2	6.3	7.0	7.2	6.2	6.3	6.4	6.8
Airplane	8.6	8.2	8.2	8.1	8.5	8.4	8.2	8.0
Bike	7.9	8.4	8.6	8.6	8.0	8.3	8.6	8.6
High velocity train	6.3	7.4	7.5	7.5	6.9	7.2	7.3	7.4
Local/Regional train	5.4	6.0	6.3	6.3	5.6	6.1	6.3	6.7

Legend: 0 – not satisfied; 10 – very satisfied

As the private car is the most preferred means of transportation it is evident in the number of Italian licensed people, especially among the people 65. The latter correspond to the 21.7% of the overall Italian population and the 19.3% of the overall Italian licensed population. Indeed, on January 2015 the number of licensed seniors in Italy was 7,408,754 out of a total of 38,475,057 valid driver's licenses. It means that about 1 driver out of 5 is 65 years or older. Data classified per age groups and per gender are shown in Table 3.2 (ACI-ISTAT, 2015).

Table 3.2 Driver's License Data – Year 2015

Age groups	Men	Women	Unknown	Total
18-24	1478033	1134462	7	2612502
25-49	9427746	8527455	6253	17961454
50-64	5724293	4726814	41240	10492347
65 and older	4880637	2457686	70431	7408754
Total	21510709	16846417	117931	38475057

Table 3.3 shows the mobility radius per age groups. In 2014 there was an increase of the proximity and short radius mobility, whereas the local, medium distance and local distance mobility decrease.

Table 3.3 Mobility radius per age groups

Age groups	2013					2014				
	Proximity Mobility (1-2 Km)	Short Distance Mobility (3-5 Km)	Local Mobility (6-10 Km)	Medium distance Mobility (11-50 Km)	Long Distance Mobility (+ 50 Km)	Proximity Mobility (1-2 Km)	Short Distance Mobility (3-5 Km)	Local Mobility (6-10 Km)	Medium distance Mobility (11-50 Km)	Long Distance Mobility (+ 50 Km)
From age 18 to 24	14.7%	20.6%	24.4%	33.7%	66.6%	23.4%	21.0%	22.4%	28.4%	47.3%
From age 25 to 49	18.5%	21.8%	25.6%	30.6%	35.6%	26.9%	23.1%	20.6%	26.7%	27.0%
From age 50 to 64	25.4%	23.8%	21.6%	26.6%	26.0%	28.8%	24.1%	20.8%	24.3%	20.7%
Over 65	40.9%	24.6%	15.5%	16.9%	21.3%	43.4%	23.0%	17.7%	13.9%	19.7%

In detail, seniors prefer short trips (1-5 km) with an increasing mobility frequency compared to the previous year (2013) but as shown in Table 3.3 the elderly travel lesser than the overall (-47%).

Moreover a detailed analysis was conducted to focus on the daily distance men and women cover (see Figure 3.15) with the results that men cover greater daily distances than women (+41%).

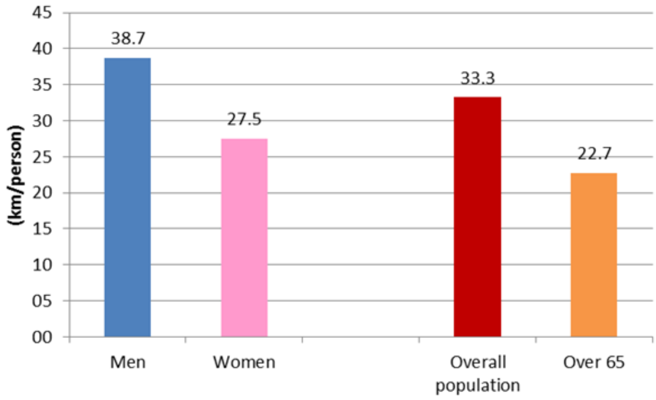


Figure 3.15 Average daily distance

Furthermore, Table 3.4 provides information concerning the mobility frequency per age groups. It is possible to point out that, in 2014, seniors are going to move everyday (28.3%). Indeed, comparing the 2013 and 2014 data, for seniors there is a growing “everyday” (+1.5%) and “3-4 times per week” (+5%) mobility to the detriment of the “1-2 times per week” (-1.4%), “Sometimes in a month” (-1.3%), “Yearly or Rarely” (-3.8%) mobility.

Table 3.4 Mobility frequency per age groups

age groups	2013					2014				
	Every day	3-4 times per week	1-2 times per week	sometimes in a month	Yearly or rarely	Every day	3-4 times per week	1-2 times per week	sometimes in a month	Yearly or rarely
From age 18 to 24	42.9	21.3	20.3	8.0	7.6	39.4	21.5	20.0	10.2	8.9
From age25 to 49	50.2	11.1	18.9	7.8	11.9	49.6	16.5	15.4	7.4	11.1
From age 50 to 64	44.6	13.3	18.4	9.3	14.4	45.8	14.4	17.2	9.4	13.2
Over 65	26.8	18.6	24.6	12.5	17.5	28.3	23.6	23.2	11.2	13.7

Figure 3.16 shows the comparison between the mean values of the overall population and the elderly values about the distance and time employed in the mobility.

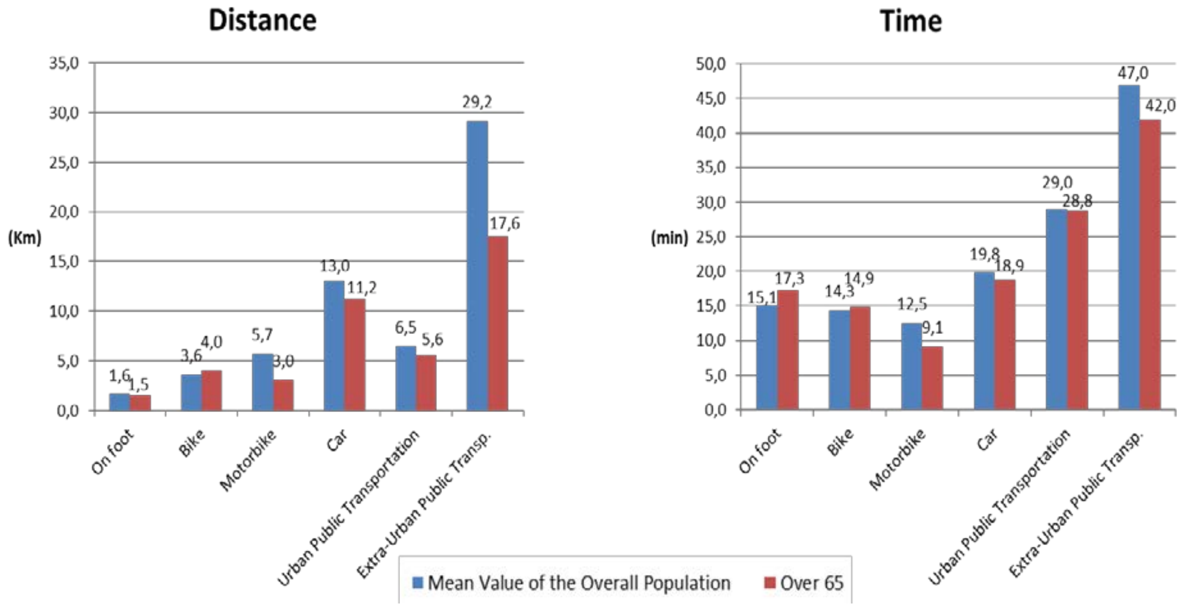


Figure 3.16 Distance and time comparison according age (year 2014)

The elderly cover distances especially by extra-urban public transportation, as well as the overall population. Seniors also prefer the car as third means of transport spending about 20 minutes per day, that is close to the time spend on foot. They spend much time by extra-urban and urban public transportation, 42 and about 30 minutes, respectively.

Finally Figure 3.17 shows the comparison between the mean values of the gender values about the distance and time employed in the mobility during the year 2014.

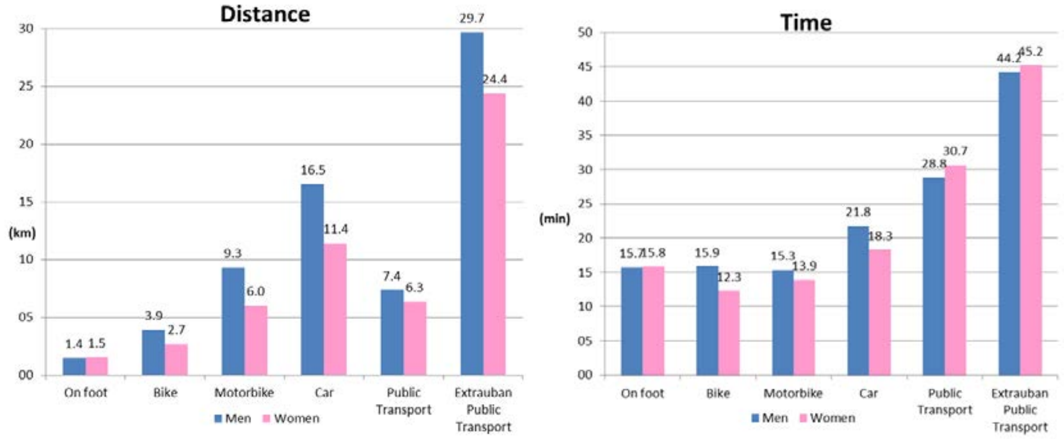


Figure 3.17 Distance and time comparison according gender

According to gender men and women cover distances especially by extra-urban public transportation. Men prefer car as second means of transport spending about 22 minutes per day. Women spend much time by extra-urban and urban public transportation, while men spend more time with motorized individual transport (car, motorbike, bike). Men and women spend the same time and travel the same distances on foot.

3.3 Mobility in Spain

In 2006 the Spanish Ministry of Public Works and Transport requested a mobility study in Spain (MOVILIA 2006/2007). It focused on working days and weekend trips and the sample was composed by 49,027 houses and people, noting nearly 230,000 movements. This study has been carried out with query answers and the information requested was regarding the day before of the interview.

In general terms, 80-85% of the population made at least one trip a day, considering both women and men respectively. 90% of people from 15 to 29 years old made at least one trip a day and the mobility decreases with seniority to a percentage of 65% (seniors with 65 years and older). This drop of mobility can be observed in Figure 3.18.

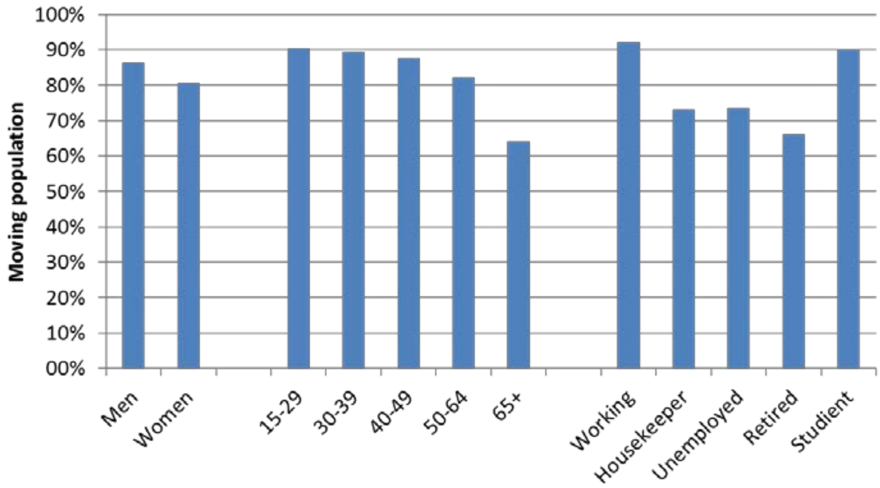


Figure 3.18 People with mobility observed in MOVILIA 2006 study

With 2.9 trips a day, men have a slightly higher travel rate than women with 2.7 trips a day. In addition, the middle age population (30-39 years old) has the highest rate of movement with 3.2 trips daily. This number also decreases with seniority to an amount of less than two trips a day for people older than 65. Regarding population activities, it can be considered that people with higher mobility (3 or more trips daily) are work or study related commuters while retired people only relocate twice a day. Figure 3.19 represents the daily trips per population, for gender, age groups and occupation.

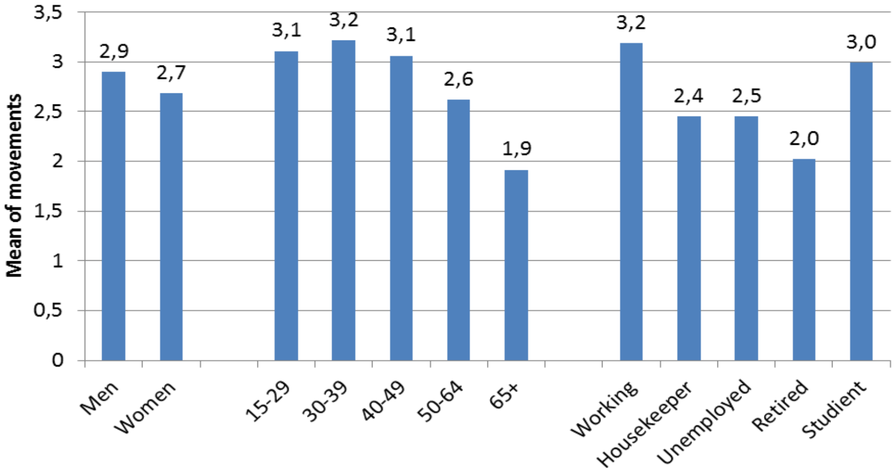


Figure 3.19 Trips a day per person

Regarding the average daily mobility in Spain (Figure 3.20, MOVILIA 2006), men and younger people spent most time during their movements. As the mean value reaches more than 60 minutes daily, most time spent in commuting is achieved by the working population with an amount of 72 minutes daily. Least time in traffic is spent by housekeepers and elderly people with both around 48 minutes.

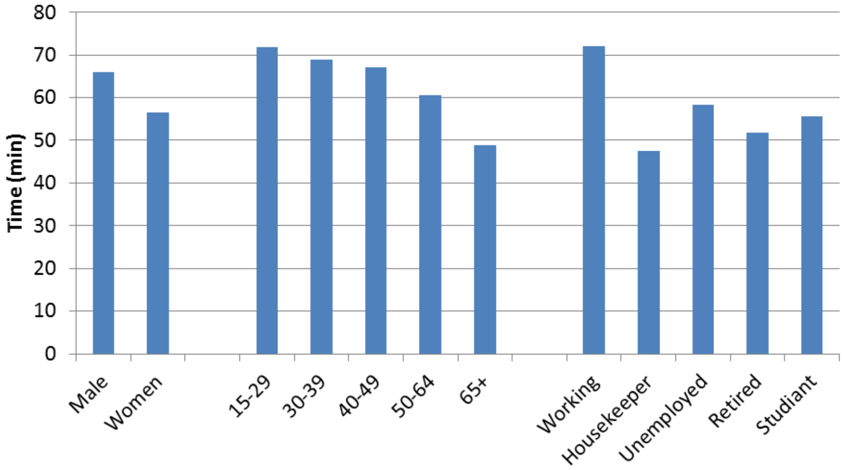


Figure 3.20 Average time for daily mobility

In Table 3.5 different modes of transport regarding the age of population are shown. It can be observed that young and elderly people realize most of their movement by foot or by bicycle, while the middle age population mostly uses private transport (either car or motorcycle). The public transportation sector has a mean value of about 10% with a majority of 15-29 year old people as its main user.

Table 3.5 Modes of transport regarding MOVILIA 2016

	Age					
	0-14	**15-29**	**30-39**	**40-49**	**50-64**	**65+**
Walking or bicycle (non-motorized way of transport)	62.9%	37.8%	33.3%	34.5%	49.5%	72.1%
Car or Motorcycle (Private transport)	27.2%	45.0%	55.5%	55.1%	40.1%	17.2%
Public transport:	5.20%	15.10%	9.30%	8.70%	8.40%	9.00%
- Urban bus or metro	3.6%	9.0%	6.7%	5.8%	5.8%	7.3%
- Interurban bus	1.4%	4.0%	1.2%	1.4%	1.5%	1.3%
- Train	0.2%	2.1%	1.4%	1.5%	1.1%	0.4%
Others	4.8%	2.1%	1.9%	1.7%	2.0%	1.7%

Considering the mobility subjected to the size of town, there are more people commuting in bigger cities, however, in metropolitan areas people are also commuting more than in towns or villages (which are not in metropolitan areas), even if they are smaller (it is considered as metropolitan area a region consisting of a densely populated urban core and its less-populated surrounding territories, sharing industry, infrastructure, and housing. Beside of this, there are more people commuting during the week than in weekends (see Figure 3.21, MOVILIA 2006). Since there is more traffic on working days than on weekends, it can be assumed that most of the traffic is related to work and study. In addition, the number of trips a day on the weekend is nearly one third lower than on working days.

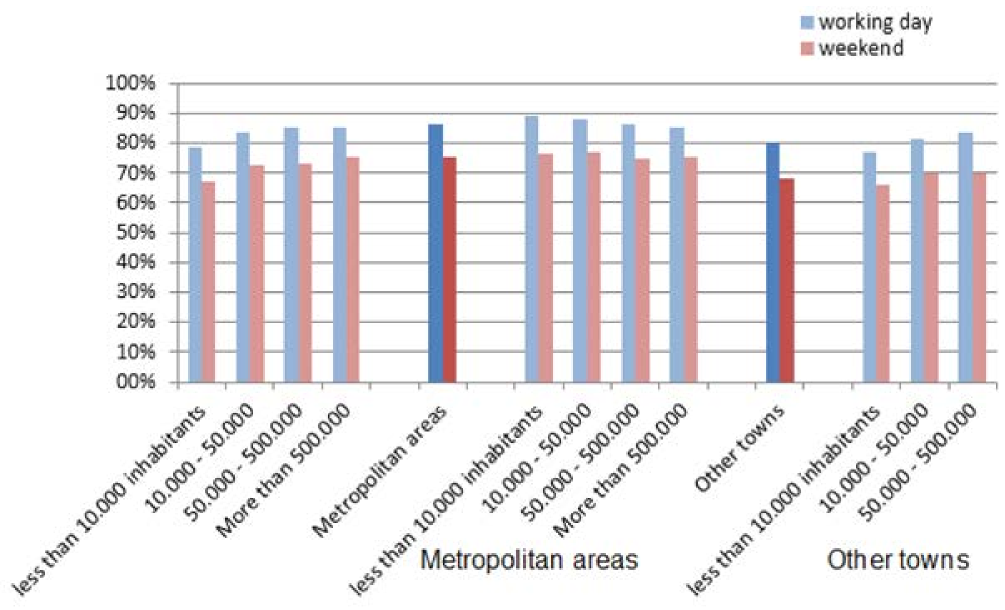


Figure 3.21 Mobility subjected to the size of town

To summarize the data provided by MOVILIA 2006, men are more mobile than women. Also, the number of moving population decreases with seniority and the main reason for commuting are related to work and/or studies. The average amount of daily trips reaches 2.8, when taking the non-moving population into account. However, this value decreases until 1.9 for people over an age of 65 years. While the younger people spent more time in their movement, the average amount spent in traffic reaches more than 1 hour. To realize this movement, the majority of the younger and older generations go by bicycle or walk, while the middle age population mainly uses private transport. The public transport reaches an amount of 10% and it is used mostly by younger people.

Finally, there is more mobility on working days than on weekends, plus the movement of the people is higher in metropolitan areas.

The number of driving licenses per age and gender could be achieved from the last five years from the DGT (Direción General de Transito), which is the official organism of traffic in Spain. In Spain, there is not a limit age when population has to stop driving. The driving license is revised (medical revision included) every 10 years until 65 years old, then is revised every five years. If the driver suffers any illness that could affect the driving capacity the revision periods are shorter, and this person could be disqualified from driving.

The number of people over 65 years with a driving license corresponds to 9% of the overall Spanish population with driving license and more than 50% of these elderly people are under 70 years old. In 2014 the number of Spanish driving licenses held by people over the age of 65 was 1,608,031 out of a total of 18,268,434. Percentagewise, 1 out of 11 drivers in Spain is 65 of age or older (see Figure 3.22).

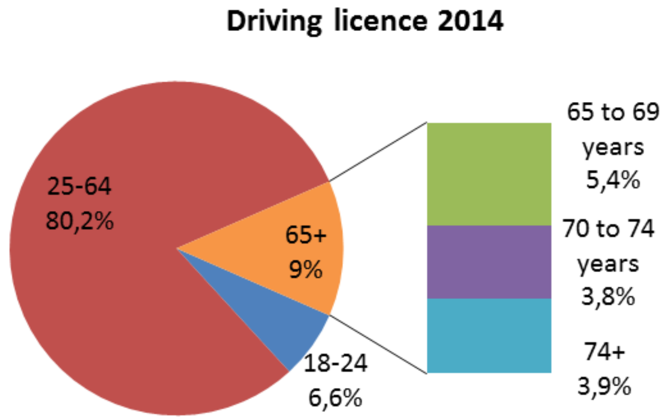
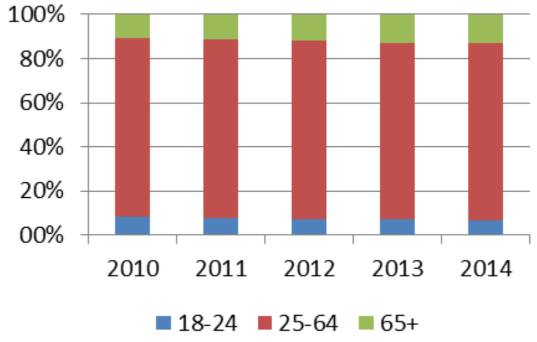
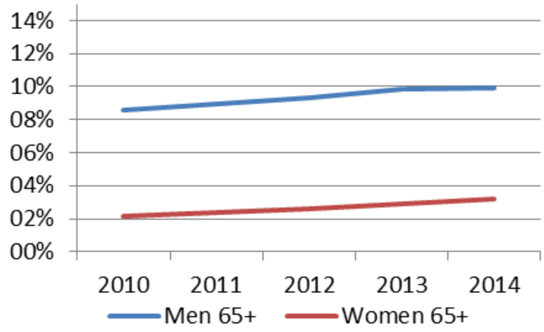


Figure 3.22 Spanish Driver License Data

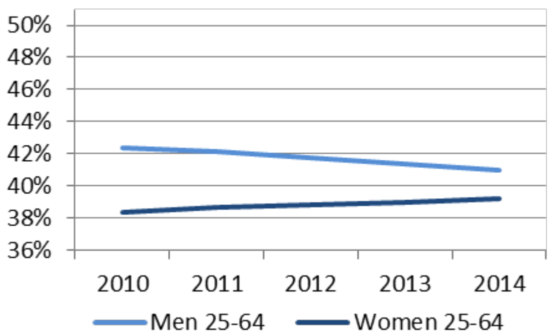
From 2010 to 2014 the share of driving licenses by age group has been very regular. The percentage of drivers over the age of 65 have slightly increased and young drivers (18-24 years old) with driving license have been slightly decreased (see Figure 3.23 a). However, big differences can be observed regarding gender. Elderly man with a driving license represents the 10% of driving population, while elderly women with a driving license are less than the 0.4% of driving population (see Figure 3.23 b). Nevertheless, every year there are more middle age women with driving licenses and therefore the share of middle age women with driving license over the total driving population has a rising trend (see Figure 3.23 c). Moreover, the share of young women and men (between 18 and 25) with driving licenses regarding the total of driving population is exactly the same (see Figure 3.23 d).



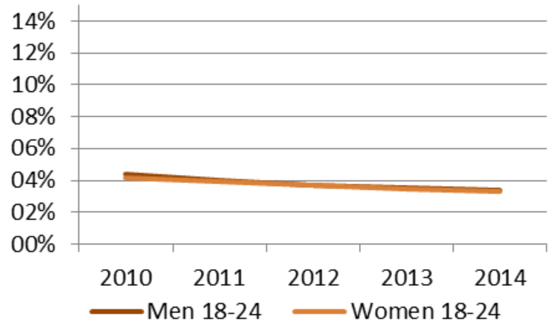
a) Shares of driving licenses by age groups



b) Trend of seniors people with driving licenseof driving license holders with the age of 65 and higher



c)Trends of driving license holders with the age between 25 and 64



d) Trends of driving license holders with the age between 18 to 24r

Figure 3.23 DGT 2014 on Driver License Data

3.4 Mobility in Barcelona

Between the years 2004 and 2014, the “Àrea de Barcelona – Autoritat del Transport Metropolità” carried out a yearly study on the working day mobility of Barcelona and its surroundings, which is titled “Enquesta de Mobilitat en un Dia Feiner (EEFM)”. The information has been obtained by telephone interviews and surveys, where people answered questions about their mobility of the day before the actual interview.

The latest poll in 2014 consisted of 9,461 people living in Barcelona, 3,966 people living in the first area around the city, 5,190 living in the second area around Barcelona and 8,851 in the third. The variables used were the total trips per day, reasons of mobility, modes of transport, age and gender.

Figure 3.24 illustrates the development of mobility along the last 10 years (EEFM, 2014). The overall number of trips per day and person increased slightly, while the elderly population increased their movement up to 50% in that time frame (from 2.2 to 3.25 trips/ day). It can be seen that older people became more active and hence, their mobility increased.

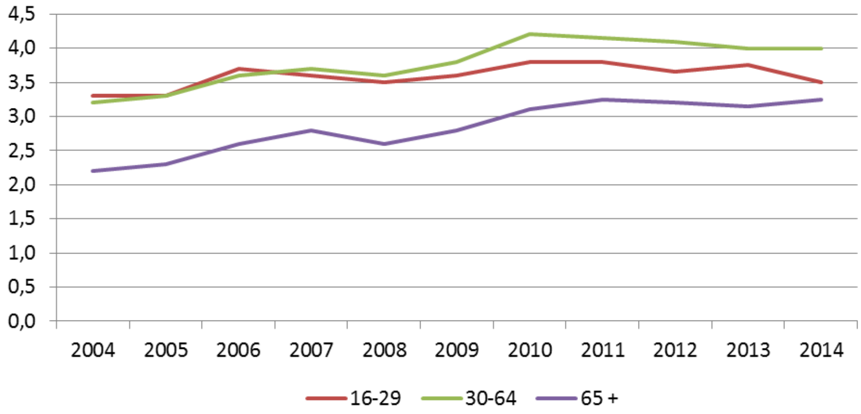


Figure 3.24 Development of trips per day per person and age group

Regarding the split of transportation modes used, the trips done by walking or by bicycle increased until 2012, while the use of private transport decreased; however, between 2012 and 2014, the exact contrary on these two transportation modes can be observed. In contrast to that, the use of public transportation had a steady decrease between 2005 and 2014. In Barcelona area, the public transport was used in 10% of cases while private transport was used in around 35% and nearly half part of trips were done by bicycle or walking (see Figure 3.25, EEFM, 2014).

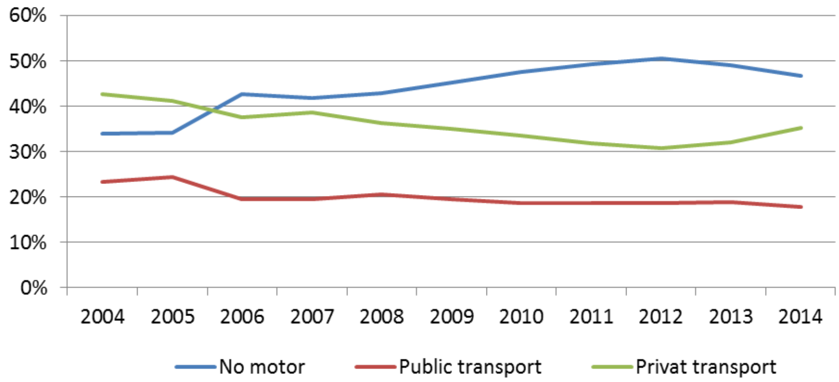
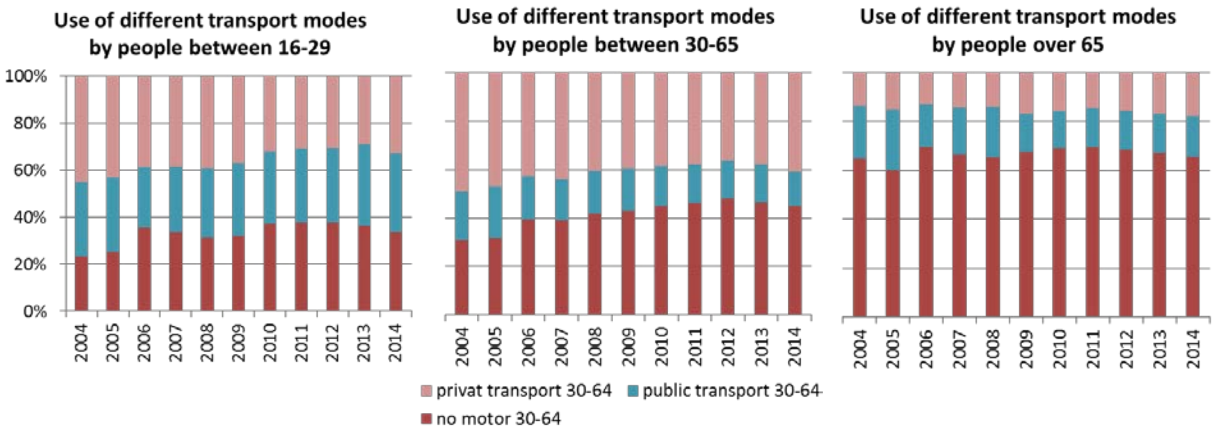


Figure 3.25 Shares of transportation modes used from 2004-2014

When comparing this data to the modes of transport regarding the age groups (see Figure 3.26, EEFM, 2014), it is noticeable that young people used less often private transport, while middle age people showed a decrease in usage of private transport but still had the highest percentage of use in this sector, the 40% of times. As for the seniors, the use of transport is quite constant along these years; they realize fewer trips via public transportation and show an increase in using private transportation up to the 20% of times.



a) People 16-29 b) People 30-65 c) People 65+

Figure 3.26 Modes of Transport subjected to the age groups

The average number of trips a day per person in the Barcelona and surrounding areas is 3.7 and for people older than 65 is 3.3. Men undertake more movements than women (see Figure 3.27, EEFM 2014). Regarding the occupation, housekeeper and unemployed are commuting more than workers or students. This result is completely different compared to the study on the mobility in Spain presented in Section 3.3.

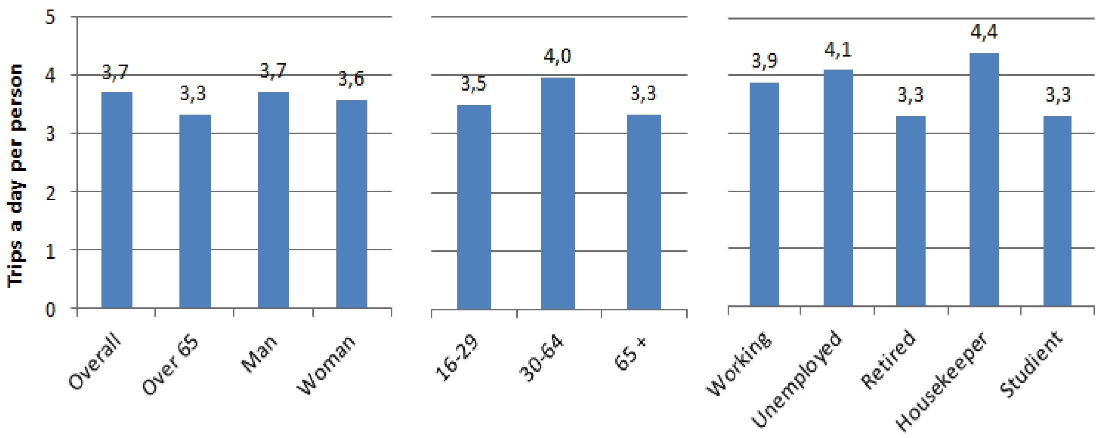


Figure 3.27 Trips per day and person in Barcelona

As for the modes of transport (Table 3.6, EEFM, 2014), people between 16 and 29 years share an equal mix of around 31-35% (no motor, public, private transport). The mid age generation is the group of people with the least usage of public transportation, while they use private and no-motor transportation equally. The elderly people over 65 years have the highest percentage of taking the bicycle or walking by foot with about 67.3%.

Taking the reasons of the mobility into account, the majority of people uses private transport for occupations like study and work, while they walk or take the bicycle for their personal transportation.

Table 3.6 Modes of transport subjected to the age group

	16-29	30-64	65 +
No motor	33.7%	43.6%	67.3%
Public transport	34.8%	13.5%	17.2%
Private transport	31.6%	42.9%	15.4%

	Non motor	Public transport	Private transport
Occupational mobility	21.5%	29.4%	49.0%
Personal mobility	57.8%	13.0%	29.2%

3.5 CONCLUSIONS

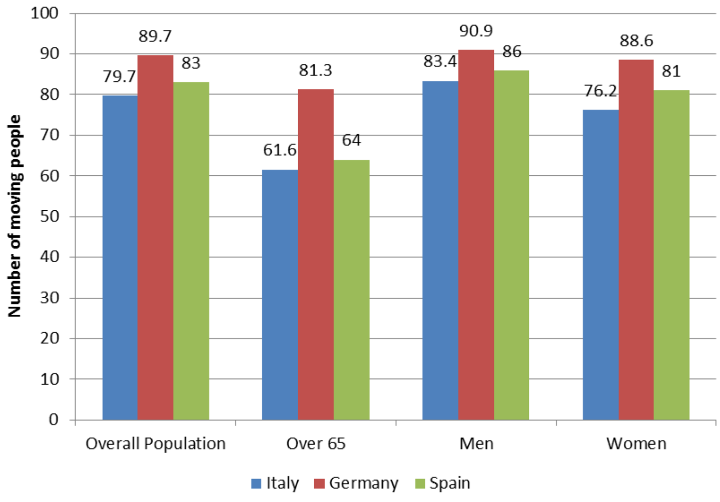
The findings of the comparative study on mobility patterns in the ageing European populations provide a comprehensive insight not only in the state of the actual mobility behaviour in relation to a wide variety of influencing factors, such as gender, age, health, major life transition points (retirement and the transition from a multi- to a single-person household), but also on data availability and the way certain variables are assessed in course of social surveys in the fields of transport and mobility.

Data analysis (in Germany, Spain and Italy) and literature researches show that mobility of elderly is increasing. Older road users travel more than their comparable age group a generation ago, but when comparing mobility data across age groups today, seniors are “less mobile” than younger age groups (i.e. have lower rate of persons who leave their house per day, fewer journeys per day, shorter distances).

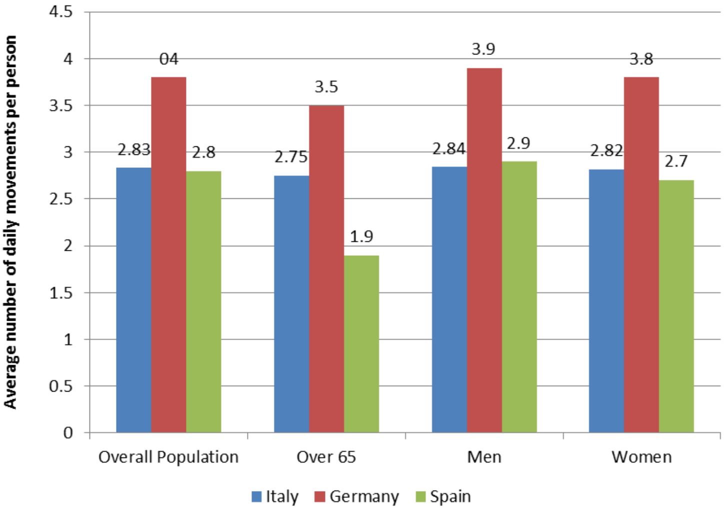
Although mobility data are referred to different sampling years (Spain 2006, Germany 2008 and Italy 2014), a comparison between the elderly habits in the three countries was conducted. The comparison is influenced by the environment, the social and demographic features of the different European countries investigated.

Globally the detailed analysis shown in the previous paragraphs highlighted that **men of all three countries do more trips a day and cover greater daily distances than women.**

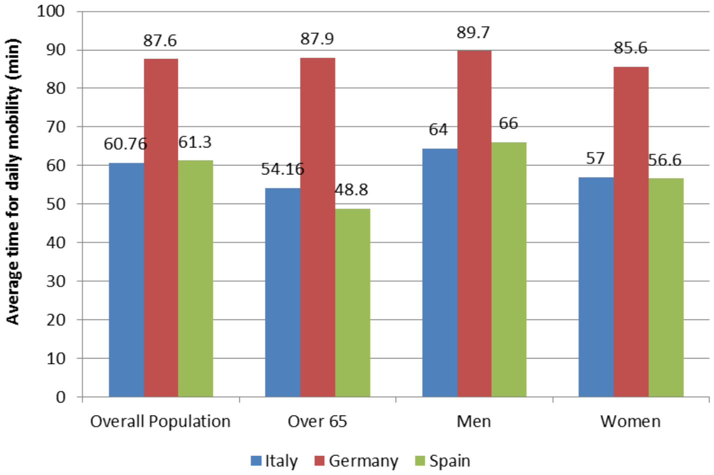
Figure 3.28 a, shows that the number of moving people in Germany is higher than in Italy and Spain (entire Region), in particular the number of German elderly is about one out three times higher (33%). German people move more frequently (Figure 3.28 a), for longer time (see Figure 3.28 b) and for more movements per day (Figure 3.28 c), than the other two countries, especially older road users.



a) Moving population



b) Average number of daily movements/person



c)Average time for daily mobility

Figure 3.28 Mobility behavior of the older age groups in Italy, Germany and Spain

In addition German people in 2008 moved more frequently, for longer time and distances with respect to Italian people in 2014 and Spanish people in 2006. It is also possible to point out that in general German values are greater than the Spanish values which at same time are greater than the Italian one, meaning that the percentage number of German people who leave their house on a given day is higher. Independently by difference between the three countries **seniors move every day for around one hour**, with a maximum of about one and half hour for German people. The same evaluation is valiant considering gender differences.

Considering free time and family reasons it appears that the elderly preferred means of transportation is walking. Walking is the transport mode preferred by the Italian and the Spanish elderly, even though motorized individual transport in Germany is a lot higher than for other modes of transport. On this matter the Italian and Spanish data are roughly comparable and the changes over the years are negligible. Italian men and women spend the same time and travel the same distances on foot.

In addition another means of transport used commonly is the private car.

Motorized individual transport is popular among German, Spanish and Italian older road users, actually rate of **elderly driver's license owners has risen over the years**. And high rate of new cars (large executive cars) are associated to German senior households compared to other age groups. In Germany the car is typically used for longer distances and time as it is in Italy.

Considering the use of the public transport, Italian seniors have at least one trip per day and spend longer time spans on this kind of transportation than German seniors.

With respect to **gender women spend much time by public transport while men spend more time with motorized individual transport** (car, motorbike, e-bikes/pedelecs), about this the number of driving licences in charge of elderly men are higher compared to elderly women.

Considering the use of the bicycle in Germany the proportion of e-bikes/pedelecs compared to other kind of bikes is rather small in group of seniors, but proportion of e-bikes/pedelecs among seniors compared to overall population is higher. In Spain more than 60% of the elderly uses non-motorized means (walking or traditional bike), but mainly they are pedestrians. In Italy the usage of bicycle reduced from 2013 to 2014. Cycling is preferred by Italian seniors especially during free time and for short trip (around 4 km).

4. PERFORMANCE CHANGES WHEN AGING

Driving is a complex task as it requires continuous information processing and appropriate and timely reactions to environmental cues. Thus driving requires optimal levels of performance in order to minimize the risk of collision. The ageing process brings about changes to an individual's ability to move, perceive and react to their environment. As society continues to age, and the use of the private vehicle remains at the centre of mobility and transport around the world, age-related decline in motor, visual and cognitive functions are therefore an important consideration for road safety.

This chapter focuses on how age-related changes affect driving performance and possible interventions, that can help identify drivers at most risk (regardless of age) and can help improve on the factors important to driving, are discussed.

4.1 AGE-RELATED DECLINE AND EFFECTS ON DRIVING

4.1.1 Psychomotor and motor decline

The inverse relationship between increasing age and decreasing function is possibly most outwardly evident in relation to psychomotor functioning. Age and health-related decline in the ability to move can manifest in a range of ways including as reduced range of motion, trunk and neck mobility, strength, difficulty with coordination and balance, and slowing of movement (Seidler et al., 2010; Staplin, Lococo, Stewart, Decina, 1999; Eby, Trombley, Molnar, Shope, 1998; Janke, 1994).

One of the most important features of age-related motor decline relates to range of movement and flexibility. In an early review by Staplin and colleagues (1999) the relationship between lower and upper limb movement and crash risk are discussed, particularly within the context of work by Marottoli and colleagues. Marottoli and colleague's work found that walking speed on the rapid-pace walk test (for this study, it was a physical measure of lower limb mobility where the participant was asked to walk 10 feet up and back as fast as the participant feels safe and comfortable) was inversely related to adverse traffic events, such as traffic crashes and violations (e.g. slower walking speed). The study by Marottoli et al. employed a sample of 283 elderly drivers (aged 72-92) and found that 9% of 'faster walkers' (i.e. those who completed the walk in a shorter amount of time) reported adverse driving events, compared with 17% of those classified as 'slower walkers' (i.e. those whose timed performance was slower). This difference between groups was found to be significant (Marottoli et al., 1994, as cited in Staplin et al., 1999).

Pedal errors (such as failing to stop or accelerating inappropriately) can also be a sign of decreased physical performance, and research has shown that elderly drivers who commit more pedal errors may be at higher risk of being involved in a crash (Freund, Colgrove, Petrakos, McLeod, 2008, as cited in Lang et al., 2013). Reduced upper limb movement, particularly difficulty reaching and extending the arms, has also been found to be associated with crash involvement in drivers aged 55 and over (Staplin et al., 1999).

Inflexibility in the joints, particularly the ability to rotate the neck, can lead to difficulties while driving. For example, a study by Dukic and Broger (2012) assessed driving behaviour and neck flexibility with fifty drivers aged 35-55 (younger group) and 75+ years (older group). The researchers identified that (compared with younger drivers) older drivers had significantly less neck flexibility; limitations in this area can lead to difficulties in checking mirrors or looking over the shoulder and observing blind spots (Eby & Molnar, 2012). A more recent study by Reed and colleagues also measured participants' neck flexibility by assessing their ability to detect targets presented more than 180 degrees around from their head position. In a sample of 32 participants (divided into four age groups, from youngest to oldest), researchers collected data on a number of measures between driving sessions in a simulator (a total of six drives per participant). Other than measuring neck flexibility, the researchers also collected data relating to contrast sensitivity, visual acuity, choice reaction time, and other previously validated scales measuring self-reported driver behaviour and attitudes. The study found that neck flexibility reduced with age, particularly for the older age group (mean age 79 years). Hence, the latter group of drivers was significantly more restricted in their neck movements than the younger age groups which could impact their assessment of complex road scenarios, such as intersections (Reed et al., 2012).

Other areas of age-related decline are discussed in the literature, including psychomotor coordination and loss of strength. Psychomotor coordination relates to a person's ability to coordinate, control, and orient parts of his or her body, and has been related to a reduced ability to use vehicle controls (Kelso, 1982; as cited in Eby & Molnar, 2012). Similarly, joint stiffness and/or muscle weakness have been associated with increased reaction times (Eby & Molnar, 2012). Sayer, Gibson and Cook (2011) discuss declines in muscle power and performance and report that muscle strength can decrease by up to 25% in older adults, which in turn can affect a driver's ability to steer the vehicle and/or apply the correct pressure for braking (Sayers, Gibson, Cook, 2012).

However, much of the decline in motor function is intrinsically related to changes in brain function and activity. Seidler and colleagues state that the causes for motor deficits are multi-factorial and relate to declines in the motor cortical regions (the area of the brain responsible for motor capabilities), as well as changes in the central nervous systems and sensory receptors (Seidler et al., 2010). This is evidenced by a study by Romoser and Fisher et al. (2009) who tested 54 older drivers (aged 70-89 years) in a simulator and on-road driving scenario and found that cognitive, and not physical, decline was significantly correlated with decreased side-to-side scanning of the road while turning. This is seemingly different to the findings by Reed et al. (2012); however, in the latter study participant's neck flexibility was measured as the maximum angle through which participants could recognise targets when viewing over their shoulder. In Romoser and Fisher's survey this was a simpler (dichotomous) procedure where researchers noted if a participant had undertaken a second side glance (i.e. side-to-side scanning just after the driver began to roll into the intersection) or not. Technically, the measure used by Reed et al. did not directly relate to the driving task, and as such may be limited. In addition, different measures and analysis techniques were utilised (Reed et al. compare scores for different age groups; Romoser and Fisher analyse the predictors of 'secondary looks'), which could explain some of the differences observed.

However, scanning of the road environment may also relate to visual behaviour. Therefore, although some of the research highlighted in this section may provide evidence of the relationship between crash risk and motor function, this relationship is likely to be mediated by visual and cognitive decline. These are discussed in Sections 4.1.2 and in 4.2.

4.1.2 Visual decline

There is no doubt that vision and visual performance are central to the driving task. Neuroimaging studies have shown decreases in occipital lobe activity (i.e. the cortical region of the brain associated with visual processing) as a function of increasing age (Dennis & Cabeza, 2008). Similarly, the ageing process triggers changes to the optical system itself (such as the lens and retina), and increases susceptibility to conditions such as cataracts (Staplin et al., 1999; Eby et al., 1998). These changes to the structure and functionality of the visual system affect visual acuity and contrast sensitivity, which have been found to relate to increased crash risk in elderly drivers.

Visual acuity can be briefly described as an individual's ability to perceive spatial detail at a given distance and can relate to a driver's ability to perceive (and, importantly, respond to) environmental cues such as road signs, vehicles and other road users. Two types of acuity emerge consistently in the literature: static visual acuity (the ability to perceive a stimulus that is stationary) and dynamic acuity (the ability to perceive a moving target). Both types of visual acuity have been found to decrease with age (e.g. Poulter & Wann , 2013). For example, a population-based study in Australia with individuals 49 years and older found that the proportion of drivers with visual impairment, measured in terms of visual acuity (employing the logarithm of the minimum angle of resolution - LogMAR), increased with age from 0.8% of people 49-54 years of age to 42% of people 85 years and older (Attebo, Mitchell, Smith, 1996). Visual acuity has been associated with on-road difficulties such as sign recognition and hazard avoidance (e.g. Higgins & Wood, 2005, as cited in Reed et al., 2012), dynamic acuity has been found to have a stronger relationship to driving errors than static acuity (Janke, 1994; Staplin et al., 1999). There is also some evidence that dynamic acuity decline is steeper and emerges at an earlier age (Eby et al., 1998).

A study by Reed et al. (2012) sought to gain a better understanding of vision and visual behaviour across age groups, including changes in visual acuity, when driving. In a study involving drivers age 17 to 75+, the authors found that the youngest drivers (17-26), had significantly better visual acuity than those in the older age groups as measured by the standard LogMAR (Log of Minimum Angle of Resolution) chart (Bailey & Lovie, 1980, as cited in Reed et al., 2012). However, the oldest group (those aged 75 years and older) had the lowest mean acuity scores. Similar findings are discussed in Janke (1994) and Staplin et al.'s (1999) reports.

Many countries use standardised measures of visual acuity as part of the re-licensing procedure for elderly drivers after a specified (though sometimes arbitrary) cut-off age (Siren et al., 2013). Some of these, particularly the United States, have reported improved safety effects of the introduction of visual acuity checks (Levy et al., 1995, as cited in Siren et al., 2013) although evidence generally points to the relatively poor value of visual acuity tests in predicting crash outcomes. A study by Mitchell (2008) comparing the driving licence renewal procedure in seven European countries (varying in stringency, age and medical/and or physical assessments required) concluded that there was no evidence that such approaches improve safety.

Contrast sensitivity, the ability to detect an object against its background, is another function that worsens with age, a finding that was also replicated in Reed et al.'s study (2012). Contrast sensitivity is particularly important in low light and or/ low visibility conditions such as fog or glare when the contrast between objects and their background is reduced. Contrast sensitivity is important for perceiving the presence of objects, such as other vehicles and/or road users.

A study by Ortiz and colleagues (2013) sought to examine the effects of ageing (particularly visual impairment) in seventy drivers (55 with normal vision and 15 older drivers with cataracts) aged 25 to 60 years and older. Participants were divided into three groups (younger, mean age 25; middle-aged, mean age 44; and older group, 60+ years) and assessed on measures of visual acuity, contrast sensitivity, visual discrimination capacity and optical quality. The study found that visual function, and in particular contrast sensitivity, deteriorated with age. This was particularly true under low-illumination conditions where older drivers exhibited a reduced ability to detect peripheral stimuli (Ortiz, Castro, Alarcón, Soler, Anera, 2013). Another study by Owens, Wood and Owens (2007) found similar results in a sample of 24 young (mean age 22 years), middle-aged (mean age 47 years) and older participants (mean age 72 years). The authors investigated the effects of age and low light conditions on speed, lane keeping and visual recognition on an on-road test (on a closed track). Although no significant age-related differences were found in speed or lane-keeping behaviour, visual recognition of targets (e.g. avoidance of road hazards, such as pedestrians) decreased as a function of age. In terms of the pedestrian recognition (using stationary foam targets), both middle-aged and older groups performed significantly worse than the younger group. The greatest differences between groups were found in the section which included sign and signal recognition, give way, lane keeping and judgement abilities (among others). This is particularly important as much research supports the finding that the ability to drive under low light conditions, such as at night-time, can decrease with age.

Contrast sensitivity (and visual ability in general) is also important to driving as it may be important in enabling higher order cognitive processes important to driving, such as hazard perception (HP) and attention allocation. For example, work by Horswill et al. (2008) investigated the hazard perception (HP) ability in a sample of 118 drivers aged 65 and older based on a video-based HP test. The authors found that although HP response times increased with age, this could be accounted for by scores in measures of contrast sensitivity, useful field of view and simple reaction time. Similarly, useful field of view (UFOV), a measure of visual and cognitive attention allocation, has consistently been identified as a predictor of driving errors and even collisions (e.g. Selander, Lee, Johansson, Falkmer, 2011; Ball, Owsley, Sloane, Roenker, Bruni, 1993). As UFOV is believed to be more closely related to cognitive processes, it is discussed in the next Section (Cognitive decline).

In fact, many visual functions involve some level of cognitive processing and there is some obvious overlap between cognitive and visual components in tests that use visual stimuli to determine performance. It is commonly accepted that visual tests alone are inadequate for predicting driving performance and need to be used in combination with tests of cognitive ability (Haymes, LeBlanc, Nicolela, Chiasson, Chauhan, 2007). This may be why, despite increases in vision testing, the countries that have put such measures into place have not been able to identify any real safety benefits. This said, evidence showing the effectiveness (or lack thereof) of such measures is limited. A Cochrane review (considered the gold-standard methodology in systematic reviewing) was undertaken in 2014 in order to gain a better understanding of the effectiveness of visual measures as a part of relicensing process. The authors concluded that there was not enough evidence to support the use of visual function measures with older drivers (Subzwari et al., 2014). Nonetheless, authors around the world continue to debate the issue of relicensing procedures.

Finally, at the beginning of the section it was highlighted that age can increase the risk of ocular disease, such as cataracts. Although this is an important factor in determining driver safety, it does not solely account for driving deficits as some evidence suggests that older drivers are less safe even in the absence of visual impairment. A study by Gruber, Mosimann, Müri, Nef (2013) reviewed existing literature on night driving ability and found that visual functions central to night-time driving were subject to age-related decline, even in the absence of ocular disease. For example, decreased mesopic vision (the type of vision used in low but not quite dark lighting situations) was found to be associated to night time collision involvement and/or subjective perceived driving disability at night for elderly drivers. Decreased photopic vision (vision under well-lit conditions) which was found to relate to the perception of signs, signals and other road users, was also found to be related to at-fault night collision (Lachnmayr et al., 1998 , as cited in Gruber et al., 2013) and night driving difficulty (o McGwin et al., 2000, as cited in Gruber et al., 2013). In a sample of 137 drivers of different ages (including 47 older subjects with visual impairment, mean age 70.6 years), Wood and Mallon (2001) also found that older drivers, with and without visual impairment, were rated as being less safe than the younger and middle-aged drivers. The study involved an on-road driving test (as well as other measures of visual function) rated by a professional driving instructor. This would suggest that, although vision may be an important feature for driving, there must be other mechanisms at play that may increase the risk to older drivers.

4.2 COGNITIVE DECLINE

Neuroimaging techniques have allowed the understanding of higher-order cognitive processes and how these relate to age-related changes in brain structure and functionality and, ultimately, task performance. Research has found that as humans age, different areas of the brain, such as the frontal and parietal lobes, begin to show signs of atrophy as well as declines in white and grey matter volume; changes to the frontal lobe are of particular importance as this is the cortical region most commonly related to executive function and decision-making (Dennis & Cabeza, 2008). Another important finding of neuroimaging studies suggests that age-related decline is heterogeneous; Dennis & Cabeza's (2008) review highlights how longitudinal (i.e. studies that measure the same participants over time) estimates of changes in the brain exceed those of cross-sectional work (i.e. studies that measure different participants of different ages, at the same point in time) (Dennis & Cabeza, 2008; Salthouse, 1996). Similar work also shows that there is much individual variability in cognitive decline, particularly as not all brain regions show simultaneous (or even age-related) functional decline (MacPherson, Phillips, Della Sala, 2002; Hedden & Gabrieli, 2004).

Age-related changes have been identified mainly in relation to attention, executive function and speed of processing (Hedden & Gabrieli, 2004; Dennis & Cabeza, 2008). However, although some research has identified relationships between such functions and declines in driving ability and/or increased crash risk, it is important to recognize the limitations in the comparability across studies, particularly as constructs such as executive function are complex and often involve several overlapping processes. In fact, cognitive functions (as well as elements of motor and visual performance) are intrinsically related and, as such, it is perhaps the cumulative effect on multiple systems that is of real importance when it comes to understanding older driver behaviour. For the purpose of this review, the focus will be on key cognitive processes related to cognitive decline measurements and increased crash risk, respectively, for attention and speed of processing. These will be discussed separately (in Sections 4.2.1, 4.2.2 and 4.2.3 below).

4.2.1 Cognitive decline measurements

The DRIVE IN[2] project ("DRIVEr Monitoring: Technologies, Methodologies and IN-vehicle INnovative systems for a safe and eco-compatible driving") provides recent evidence of cognitive decline at older ages (e.g. experimental data). The project was coordinated by Fiat Chrysler Automobiles (FCA Italy) and it was partially funded by the Italian Research Ministry within the National Operative Programme for research (PON) 2007-2013. The project assessed the individual differences relating to driving behaviour, particularly, the relationship between driving performance and internal (such as gender and age) and external factors (such as cognitive load and environmental aspects) (Coluccia, Gamboz, Brandimonte, 2013). The study sample was composed by 120 volunteers, split as follows:

- 40 young people (18-26 years old): 20 males and 20 females
- 40 adult people (27-64 years old): 20 males and 20 females
- 40 elderly (65-75 years old): 20 males and 20 females

A driving simulator was used and a detailed test protocol was developed based on a Lane-Keeping Task (taking 3 minutes for each driving session) and on different types of road scenarios (highway and mountain driving). Two levels of cognitive load (high vs. low) were also tested. Cognitive load was induced by a secondary task (Cnossen, Rothengatter, Meijman, 2000): while driving (primary task) participants had to listen to a list of 15 highway-cues (city name + kilometres of cue). At the end of the list, they were asked to speak aloud the name of the city with the longest cue.

The main findings show that in order to perform both primary and secondary tasks, participants in the higher load condition reduced their travelling speed; whenever speed is reduced, stability increases (lower SD). Importantly the driving behaviour of elderly participants in the sample was found to be very similar to the overloaded participants' behaviour. Moreover gender, age, kind of road, and cognitive load are all important factors affecting driving performance.

4.2.2 Visual attention

Attention is the means by which we process a limited amount of information from our external and internal environment (Sternberg, 2006). Regardless of age, there are limitations to how much information can be processed at any one time, and as such allocating attention to the correct elements within the environment is a vital component of safe driving. Similarly, visual attention can be affected by different components, such as target depth and position (Pierce & Andersen, 2014), further highlighting its relevance to safe driving at all ages.

There is good evidence to support a link between attrition in visual attention and crash risk (e.g. Wagner, Müri, Nef, Mosimann, 2011). Thus, a number of tests have been developed to measure visual attention; the most commonly used in road safety is the Useful Field of View Test (UFOV).

The UFOV is a computer-based visuo-cognitive test measuring processing speed for divided and selective attention tasks (Selander et al., 2011). Research has shown that lower UFOV scores are associated with driving errors and crashes (e.g. Ball et al., 1993; Bélanger, Gagnon, Yamin, 2010; Mathias & Lucas, 2009; Clay et al., 2005; Janke, 1994). A study undertaken in 1993 with a sample of 294 participants aged between 56 and 90 years found that UFOV was the strongest correlate of crash frequency in the five years preceding the study. The study also gathered data on visual health (and ocular disease), central and peripheral vision and mental status (Ball et al., 1993). Moreover, a meta-analysis undertaken in 2005 showed that poorer UFOV performance was consistently associated with negative driving outcomes; this effect remained when the weighted mean effect size was calculated across studies (Clay et al., 2005). Since then, further research on the topic has continued to demonstrate a relationship between UFOV and crash risk. For example, a study by Selander and colleagues in 2011 employed 85 volunteers (ages 65-85 years) without cognitive impairment who were assessed on a number of measures including UFOV, self-rated driving performance and scores on two on-road assessments (completed by an occupational therapist). The results showed a positive correlation between UFOV scores and both on-road assessments (Selander et al., 2011).

However, as with other age-related declines, there is a lot of individual variability among older drivers in their performance on UFOV. Therefore, as highlighted by Edwards and colleagues, this tool may be most effective at identifying individuals with clearly intact or impaired function (Edwards et al., 2006). Indeed, researchers have even begun to identify what are believed to be appropriate cut-off scores for the test when identifying drivers more likely to be involved in an at-fault collision. Ball et al. (2006) suggest that participants who performed at 353 milliseconds or worse on one of the subsets of the test (relating to divided attention) were 2.02 times more likely to incur an at-fault crash over the subsequent three years.

However, the appropriateness of UFOV as an assessment tool should be carefully considered; as Edward and colleagues suggest, UFOV may be most useful as an identification tool for individuals who are clearly intact or impaired and may not be as efficient at identifying those with lesser degrees of impairment (Edwards et al., 2006).

Another visuo-cognitive function that has been studied in relation to elderly driver safety is visual search behaviour. Findings in this area of research suggest that older drivers may attend to particular areas within their field of view less frequently than their younger counterparts (Pollatsek, Romoser, Fisher, 2012). This may indicate key differences in their scanning of the environment, which can have serious repercussions on road safety (Lavallière, Laurendeau, Simoneau, Easdale, 2011; Dukic & Broberg, 2012).

Some studies have identified that driver's visual search behaviours can be a key cause of collisions. The study by Reed et al. (2012) has previously been discussed and additional findings from the study indicate that older drivers spent less time scanning to the left and right before proceeding at an intersection. Similarly, work by Lavallière and colleagues found that older drivers (ages 65-75 years) conducted visual inspections toward the rear-view mirror and blind spot less frequently than younger drivers (ages 21-31 years). Limitations in scanning of the environment may not be the only issue faced by elderly drivers. Dukic & Broberg (2012) conducted a study that showed that while middle-aged drivers spent more time looking at dynamic objects within their environment (such as other vehicles), older drivers (aged 75+) seemed more concerned with positioning and thus spent more time looking at lines and markings on the road. Hence, not only are elderly drivers spending less time scanning the environment, they may also be focusing on different cues altogether.

There is some evidence that differences in search behaviour by older drivers are a consequence of the strains of multiple demands (load) on the cognitive system. A study by Romoser and Fisher identified that in a sample of 54 drivers aged 70-89 years, it was the participants' cognitive function (and not their physical health) that significantly predicted side to side glances in both a simulator and on-road trial (Romoser & Fisher, 2009). Lee and colleagues undertook two experiments in the United States with twelve participants each in order to understand the effects of cognitive load on visual attention. Cognitive load was measured by using a combination of auditory and visual tasks where participants were asked to respond to changing stimuli while performing a simulator driving task. Although the study did not involve older drivers (the mean participant age was 25 years), the authors found that both cognitive load and short glances away from the road increased drivers' tendencies to miss safety-critical events (Lee, Lee, Boyle, 2007). Given the knowledge that age increases the likelihood of decreased functionality in various domains, it would be expected that the effect of cognitive load on driver's ability to detect safety-critical events would also decline, particularly when other elements such as change blindness and motion processing are considered.

Limitations in attentional capacities can lead to failures in processing of new information, resulting in change blindness. According to Rizzo and colleagues, change blindness is the failure to notice some changes in the visual environment (Rizzo et al., 2009). Although change blindness can occur because of lapses or diversion in attentional resources, it can also occur due to eye movements and blinking regardless of age (Simons & Ambinder, 2005).

Some studies have found age-related declines in change blindness as well as associations with decreased driving performance. For example, in a study by Caird and colleagues, 62 drivers were divided into four age groups: 18-25 years ('young'), 26-64 ('middle-aged'), 65-73 ('young-old'), and 74+ years ('old-old'). The method involved showing participants a series of intersection photographs that had been manipulated so that one object (e.g. pedestrian, vehicle, signs) in the scene would change when images were alternated. Young and middle-aged participants were more accurate at detecting the changes than were participants in the young old and old-old groups. Moreover, data showed that older drivers had especially low accuracy scores for the images containing pedestrians (Caird, Edwards, Creaser, Horrey, 2005).

4.2.3 Speed of processing

It is universally understood that processing speed (and reaction time) decrease as a function of age (Yankner, Lu & Loerch, 2007). Some researchers have even stated that processing speed may underpin findings relating to other cognitive functions (such as attention and decision-making) with relation to older individuals (López-Ramon, Castro, Roca, Ledesma, Lupiañez, 2011).

In basic terms, speed of processing refers to the speed with which cognitive operations can be executed. The Processing Speed Theory posits that as humans age, the speed with which internal processing operations can be executed decreases, thus resulting in impaired cognitive functioning (Salthouse, 1996). Deficiencies in the speed of processing can be particularly notable in complex tasks as, according to Salthouse, these operations depend on the products of simpler operations, some of which may be unavailable due to lower execution speeds. Therefore, a complex task such as driving, which may require numerous concurrent subtasks, is likely to be most affected by such limitations.

Evidence to support this theory is available in relation to road safety. One study involving younger (ages 20-30) and older (ages 61-83) pedestrians assessed participants' decision to cross the road in the presence of slow and faster moving vehicles. The analysis showed that motion perception (i.e. the time taken by participants to determine if the vehicle was approaching at a high, medium or low speed) was affected by age, with older participants taking longer to make accurate judgements; motion perception also played an important role in observed street crossing decisions in the experimental scenario (Cavallo, Dommes, Boustelitane, Mestre, Vienne, 2010). Shanmugaratnam, Kass, and Arruda (2010) undertook a study in which they measured various things including simulator driver performance, cognitive processing speed, psychomotor functioning, and executive function. The study found that a regression model containing all of the above measures accounted for 26% of the variance in traffic light violations. Similarly, the neuropsychological tests accounted for 28% of the variance in speeding violations and 27% of the variance in collisions. Another study, this time involving 345 licensed and active drivers over the age of 50, showed that performance on all neuropsychological tests (of which speed of processing was one of) was significantly correlated with critical errors (e.g. those that would lead to crashes, such as entering an intersection on a red light) and non-critical errors (e.g. incomplete stop) (Anderson et al., 2012).

Older drivers can face perceptual issues when judging their own or other road users' speed. This is an important factor as speed appraisals help to inform decisions regarding when it is safe to pull out of a junction or overtake another vehicle. Time-to-arrival (TTA) estimates are discussed within this context and it is widely accepted that issues such as illumination and approaching vehicle size (e.g. larger versus smaller vehicles, such as motorcycles) can have an important effect on the accuracy of such estimates regardless of driver age (e.g. Horswill, Helman, Ardiles, Wann , 2005). Again, given the combination of visual and perceptual age-related declines, it would be expected that such effects would be worsened for older drivers.

An early study by Kline and colleagues assessed 397 elderly drivers on their perceived difficulty undertaking a series of visual/driving tasks and their driving experience. The results showed that age was strongly related to items measuring visual and driving difficulties (e.g. speed judgement difficulties) (Kline et al., 1992). More recently, Poulter and Wann showed that age can result in a reduced ability to accurately gage vehicle approach speed; according to their research, this reduction translates into a difference of between 2.8 and 3.4 mph (depending on vehicle type) for every decade in age. This difference was particularly notable for participants aged 75 and over in their sample (n=19) who were unable to discriminate between one car approaching at 20 mph and one approaching at over 40 mph; this led them to the conclusion that perceptual limitations of this kind can lead to a 50% reduction in time available to perform a traffic manoeuvre (Poulter & Wann, 2013).

4.3 CRASH RISK AND ITS RELATION TO DECLINE IN KEY AREAS

It is often stated that older drivers are at increased risk of sustaining injuries when driving. One way in which this risk manifests is in the increased risk of fatality for drivers of advanced age as a result of a collision (Hakamies-Blomqvist & Peters, 2000; Mitchell, 2010). As Mitchell (2010) showed with his analysis of UK crash data, as much as 2% of 70-79 year olds and 4.5% of 80+ year olds injured in a traffic accident die from their injuries (compared to 0.6% of drivers between 30 to 49 years). This is replicated in other population-based studies, for example a study by Kent and colleagues in the United States also found that mortality rate as a result of a collision increased with age (Kent, Henary, Matsuoka, 2005). Moreover, a growing body of research has consistently shown that the increase in risk for elderly drivers does not become apparent until the age of 80 years (Mitchell, 2010); even then, the risk of collision is still lower than for the youngest driver age groups (e.g. those between 18 and 24 years).

One factor that seems to be generally accepted is that older drivers, regardless of whether they are considered to be an at-risk group, seem to be involved in particular types of road collisions. Recent research has shown that older drivers tend to be overrepresented in intersection or right of way crashes (Clarke et al., 2009; Clarke et al., 2010; Mayhew et al., 2006; Koppel et al., 2011). A report published by the Organisation for Economic Co-operation and Development (OECD, 2001) showed that the collision involvement at intersections for older drivers was double that of the youngest group (as shown by percentage values); though this was only for drivers over the age of 80. Similarly, an in depth study of a UK sample of over 2,000 reported crashes involving drivers aged over 60 for the years 1994–2005 found that the most frequent type of accident caused by drivers aged 60+ years, or 38% of the sample, was right of way crashes (Clarke et al., 2009).

When considering older driver over-representation in right of way crashes it is important to understand that it is likely to be the cumulative effect of degradation in motor, sensory and cognitive functions. In brief, physical motion and sensory perception are likely to facilitate higher order cognitive functions which allow drivers to maintain optimal levels of driving performance. Motor function, particularly difficulties rotating the neck and torso (Reed et al., 2012; Dukic & Broger, 2012), play an important role in making assessments of when it is safe to pull out of an intersection. If the driver is unable (or slower) to perform the body movements that facilitate scanning of the environment before making decisions to turn, it is more likely that their ability to avoid a collision may be compromised, particularly in complex or congested traffic scenarios. In fact, the study by Reed et al. (2012) suggested that the difficulties experienced by drivers in their study (i.e. poor positioning at junctions and less time performing visual checks) could be due to driver's slower movement in turning left and right to view the scene.

Visual performance is intrinsically linked with the ability to perceive physical objects within the driver's environment and is undoubtedly central to the driving task. Age-related changes to the eye structure and function mean that, as humans age, visibility under certain situations (such as at night or under poor weather conditions) can be significantly reduced (Eby et al., 1998; Staplin et al., 1999). Particularly important are changes to visual acuity and contrast sensitivity. Visual acuity relates to drivers' ability to perceive objects within their field of view and reduced acuity can result in drivers failing to perceive objects, such as signs, that could otherwise help guide decisions at intersections. Similarly, decreases in contrast sensitivity can result in drivers failing to detect oncoming road users, particularly under conditions of poor lighting or visibility, even if they have scanned the environment for cues (Ortíz et al., 2013; Owens et al., 2007). However, risk is also likely to be related to cognitive processes. The study by Romoser and Fisher evaluated the relative importance of physical (including motor and visual) versus cognitive performance and found that it was cognitive performance which was correlated with side-to-side scanning of the road (Romoser & Fisher, 2009). It is therefore unlikely that problems with the acquisition of appropriate sensory information are solely responsible for the increased tendency of older drivers to be involved in collisions at junctions.

When considering the range of cognitive dysfunction that has been associated with increased age, visuo-cognitive processes such as visual attention, visual search and change blindness can help explain why older drivers are overrepresented in collisions at junctions. Changes in visual search behaviours mean that older drivers spend less time looking at important peripheral and central visual regions as well as scanning the environment and checking blind spots (Pollatsek et al., 2012; Lavallière et al., 2011). This, combined with physical limitations of the visual system could increase crash risk under scenarios that require effective monitoring of oncoming traffic. Similarly, the decreased ability to direct attention at relevant stimuli and the decreases in processing speed can interfere with the ability of drivers to process safety-relevant information in a timely manner, which could result in increased errors and collisions (Cavallo et al., 2010; Shanmugaratnam et al., 2010). This could be particularly problematic at junctions as drivers are required to process large amounts of information and make decisions quickly and efficiently. If a driver is unable to attend to important events within the environment and is delayed in his or her reactions to these (due to a combination of a slowing in cognitive and physical performance), it is likely that complex scenarios (such as junctions) will result in risk.

Motion processing is another important skill for making safety-related decisions at intersections. Even if a driver is able to visually detect a target within his or her field of view, they must be able to accurately assess the travelling speed and likely TTA of the oncoming vehicle in order to decide when it is safe to pull out of a junction. As research such as that by Poulter and Wann (2013) has shown, older drivers are less efficient at making these assessments often resulting in more dangerous decisions when turning at an intersection. In addition, it is known that vehicle features (such as vehicle size) can be problematic in making correct TTA decisions in road users of different ages (Horswill et al., 2005). As such, older drivers may be at an increased risk particularly when smaller vehicles such as motorcycles or bicycles are part of the environment the driver must operate in.

4.4 Conclusions

As evidenced by the research discussed in the sections above, age brings about changes to skills central to the driving task. There are clear and well evidenced changes to motor, visual and cognitive functions which compromise drivers' abilities to negotiate complex road scenarios, such as junctions. Although these functions have differential effects on driving they share common processes and, as discussed, it is likely the combination of deficits that results in the increased crash risk for elderly drivers. However, although some data shows that older drivers may be at an increased risk of being involved in a collision, it is also their increased fragility in the event of a crash that is of concern when discussing the risks faced by older drivers.

Despite the reported increases in crash risk, a large proportion of older drivers maintain a good standard of driving performance (Reed et al., 2012; Lang et al., 2013). Moreover, there is good evidence to support the notion that older drivers are adept at compensating for their performance decline and often engage in self-limiting practices such as stopping driving at night or in heavy traffic conditions (Lang et al., 2013).

On the other hand, vehicles are becoming easier to drive (due to features such as steering assistance, lighter gear changes and emergency brake assist) making it easier for drivers with physical limitations to operate a vehicle safely. Similarly, as in-vehicle technology continues to advance, more systems are developed that can aid drivers in their decision-making while driving. Advanced Driver Assistance Systems (ADAS) are designed to help drivers during the driving task and can include systems that aid drivers with night vision and forward collision warning; in-vehicle technology, including navigation systems for example, can help older drivers by reducing the cognitive load necessary to perform the driving task (Eby & Molnar, 2012). When developing technologies to aid older drivers however, consideration must be given to the acceptability of those technologies. Passive safety systems, such as those focussed on by the SENIORS project, are also important in the event that a collision does occur. These include improved occupant restraints that are better adapted to the strength of elderly occupants, and better protection for pedestrians and cyclists. In addition, assessments of the effects on driver behaviour should also be undertaken in order to ensure such systems don't result in unintended consequences such as increasing in-vehicle distraction.

5. Behaviour in traffic

This chapter provides an overview of the travel behaviour and the road safety situation of elderly road users (drivers, car passengers, cyclists and pedestrians) in order to understand their behaviour as road users involved in car accident. Data refer mainly to the three European countries Germany, Italy and Spain as well as to the US. Statistical databases were used in order to assess specific queries. Sources of data were:

For Germany:

- Federal Statistical Office
  - Federal Statistical Office regularly provides statistical information on transport in Germany (e.g., passenger transport, vehicle stock, traffic accidents)
- infas (infas Institute for Applied Social Sciences) and German national aeronautics and space research centre (DLR)
  - conducted the Mobility in Germany survey in 2008 on behalf of the Federal Department of Transportation asking around 60 000 citizens about social demographics and mobility behaviour
- ESRA (European Survey of Road User's Safety Attitudes)
  - ESRA is a joint initiative of 17 European countries aiming at collecting comparable national data on road users' opinions, attitudes and behaviour with respect to road traffic risks
- SARTRE4 (Social Attitudes to Road Traffic Risk in Europe, 4th edition)
  - SARTRE is a survey in 19 European countries on road users' attitudes, perceptions, opinions, needs, experiences and expectations with respect to road traffic risk
- GIDAS (German In-Depth Accident Study)
  - GIDAS is a cooperation between the Federal Highway Research Institute (BASt) in Germany and the Automotive Research Association (FAT) that uses in-depth recording and analysis of traffic accidents to optimize vehicle safety, traffic planning, road construction, and transport infrastructure

For Spain:

- DGT - Microdatos de accidents (General Directorate of Traffic – accidents database)
  - DGT is the official organism of traffic in Spain that, among other activities, it records all traffic accidents with injured victims. Data form 2001 to 2013 is recorded in this specific database, where there are available, a total of 255,661 crash cases and 68 variables regarding crashes, vehicles and people involved. Moreover, there is information regarding the maneuver and the driver behaviour while the accident

occurs. Data between 2001 and 2013 have been studied in order to find any tendency for older driver behaviour.

For Italy:

- ACI-ISTAT database on road accident
    - o ISTAT is the Italian National Institute of Statistics, main producer of official statistics in the service of citizens and policy-makers. ISTAT works in cooperation with the Automobile Club of Italy (ACI) to standardize the accident data, collecting Police reports

For United States:

- CIREN (Crash Injury Research and Engineering Network)
    - o CIREN is an American multidisciplinary database which is not statistically representative for the US, but has several variables not included in other US database. It covers a ten year period (2005 through 2014) and a total of 693 accidents.

5.1 Elderly as car drivers

In the following sections the crash involvement of elderly drivers, typical accident scenarios and safety behaviour will be described.

5.1.1 Crash involvement of elderly car drivers

In Germany, transport performance was assessed in 2008 as part of the survey Mobility in Germany (infas & DLR, 2010). Drawing on accident rates reported in the respective year, it is possible to calculate crash rates per kilometre driven. As can be seen in Figure 5.1, the highest rate of injured or killed car drivers was found among the 18- to 20-year-olds. With increasing age the number dropped and remained fairly low for persons between 35 and 69 years of age. Only from an age of 70 years, the rate of injured or killed car drivers started to climb again and reached for seniors aged 75 years and older a level comparable to that of persons in their early 30s (calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010).

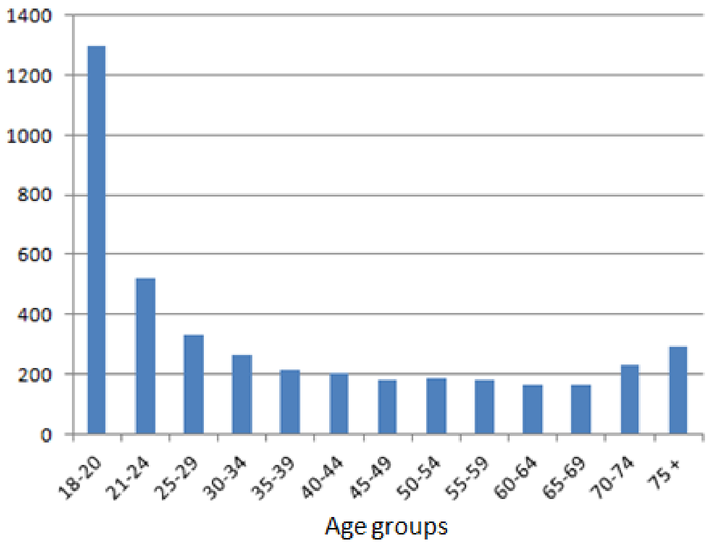


Figure 5.1 Number of injured or killed car drivers of different age groups per 1 billion kilometers driven

These numbers might even overestimate the accident risk of seniors due to different biases. On the one hand, older road users suffer greater injuries in crashes of the same intensity when compared to younger road users. This is commonly known as the frailty bias (Hakamies-Blomqvist, 1998). Since the probability of an accident being reported varies with its intensity, it can be concluded that a higher rate of accidents in which seniors are involved is registered by the police and therefore included in the statistics. As can be seen in Figure 5.2 (calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010), especially the probability of dying in an accident was elevated for senior car drivers.

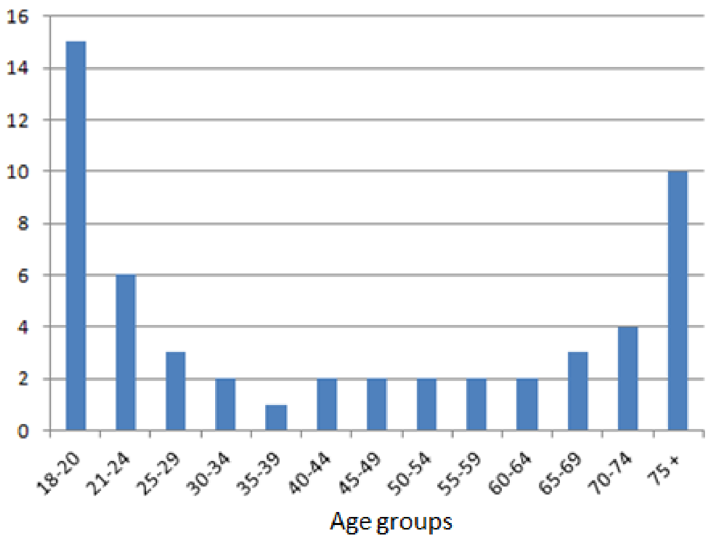


Figure 5.2 Number of killed car drivers of different age groups per 1 billion kilometers driven

While studying accident rates, it needs to be considered that the relationship between annual mileages and number of accidents per kilometre is not linear. High mileage drivers have, independently of age, lower accident rates per kilometre than low mileage drivers. Since senior drivers typically drive less than younger drivers, their risk might be overestimated (Hakamies-Blomqvist, 1998). This phenomenon is called Low Mileage Bias. Since data from Germany are not available to illustrate this bias, a study from the Netherlands will be drawn on. As can be seen in Figure 5.3 (illustration based on data from Langford, Methorst and Hakamies-Blomqvist, 2006), a comparison of the rate of accidents (of any severity) of persons of different age groups but with equal transport performance showed that most persons aged 75 years and older were safer drivers than persons from other age groups. Only senior drivers who travel less than 3,000 km a year showed elevated crash rates (Langford et al., 2006).

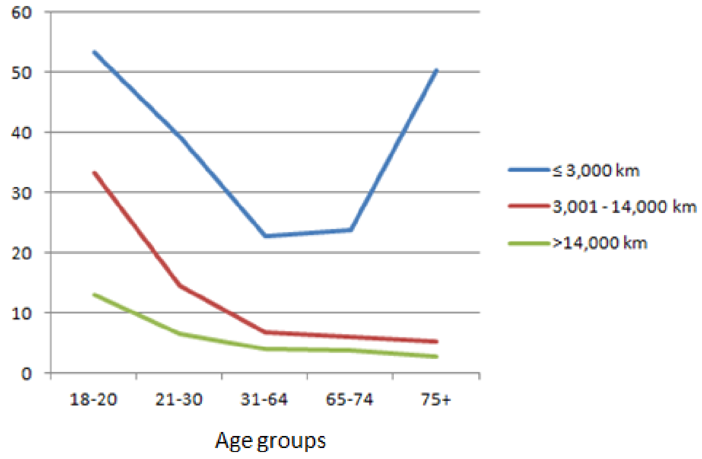


Figure 5.3 Number of accident involved car drivers of different age groups per 1 million kilometers driven, controlling for annual mileages

Furthermore, differences with respect to the environment people drive in, need to be considered. While high mileage drivers may be more likely to use freeways and multi-lane divided roadways, low mileage drivers probably travel more on urban roads with a greater number of potential conflict points (Langford et al., 2006). This difference with respect to the location of driving is called Context Bias (Fastenmeier & Gstalter, 2014). Last but not least, fatal accidents with involvement of elderly drivers are more often reported by the media, even if they are largely outnumbered by accidents of younger drivers, a phenomenon called media bias.

5.1.2 Typical accident scenarios of elderly drivers

An analysis of accident data in the UK showed that senior car occupants were more likely to sustain serious chest injuries than their younger counterparts and that these injuries were mainly due to forces exerted by the restraint system (Welsh, Morris, Hassan, Charlton, 2006). Similarly, Yee, Cameron and Bailey (2006) found that elderly victims of motor vehicle collisions have a higher risk of chest injuries, especially of chest wall injuries and that the fatality rate of the elderly group was almost double that of the younger group. The particularities of the elderly (frailty, fragility) challenge the performance of existing safety systems that are not proven to be as effective for the elderly as they are for younger road users.

To further understand the needs of the growing population of elderly drivers it is important to understand the accident scenarios and aspects in day to day traffic that may be challenging for this group (Key, Morris, Mansfield, 2016).

An analysis of typical accident situations that senior drivers in Germany are involved in, showed that especially crossing situations are challenging for elderly drivers (Johannsen & Müller, 2013 a). The rate of collisions with other vehicles that turn into or cross a road among all accidents seems to increase with age and seems to be the most relevant accident category for senior drivers. Furthermore, even though across all age groups elderly drivers have the lowest share of collisions with vehicles that are moving ahead or are waiting, in absolute numbers this kind of accident is also important for seniors. Collisions with pedestrians also occur more often with increasing age, but the absolute numbers are relatively low (Johannsen & Müller, 2013 a).

An increasing involvement in rear-end and angle crashes with age was also lately reported. In single-vehicle and head-on crashes on the other hand, elderly drivers are underrepresented (Polders et al., 2015). With respect to the driving environment, in Germany in 2014, 53.6% of senior drivers got injured or killed on urban roads, followed by 38.6% outside of built-up areas and 7.8% on express highways (calculations based on data from Federal Statistical Office of Germany, 2016).

In Germany, most common driving errors of senior car drivers that caused accidents with injury to people, were due to disregarding the right of way (22.8%) as well as due to errors when turning, reversing, entering the flow of traffic or starting off the edge of the road (21.5%). Accidents due to insufficient safety distance (11.4%), improper behaviour towards pedestrians (7.5%), and inadequate speed (6.0%) were less common. Errors when overtaking (2.9%) as well as errors due to the influence of alcohol (1.0%) were hardly registered as the causes of accidents of senior car drivers (calculations based on data from Federal Statistical Office of Germany, 2016). Unfortunately, information on accident rates due to a distraction of the driver (e.g., due to talking on the phone or texting while driving) are not available for Germany yet.

In Spain, data from the DGT database (DGT Microdatos de accidents) confirm that the most common driving injury accidents with senior car drivers happen following a route and turning or crossing, mainly when turning or crossing senior drivers have more frequently accidents than younger drivers. Overtaking and fast manoeuvre are hardly registered for all age groups but for senior drivers is even less common than for younger drivers (see Figure 5.4).

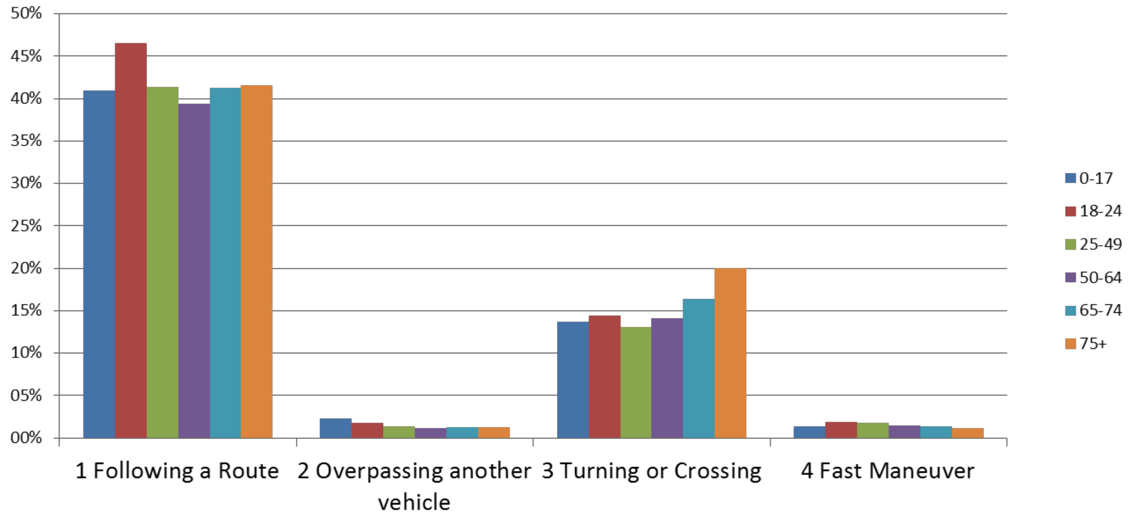


Figure 5.4 Actions with more frequent accidents associated, in Spain

In addition the analysis has shown that the severity among the people violating traffic laws increases along with the age of the drivers. Although the accidents severity linked with no traffic violations show the same trend, but the increase in severity is lower. Therefore the age group of 75+ carries out the highest injury rates accidents. The consequences in terms of injury severity are that the elderly show high percentage of slightly injured when there are no law violation, but the older (75+) reported severe injuries when distracted, or violating traffic signals, or driving without care (see Figure 5.5).

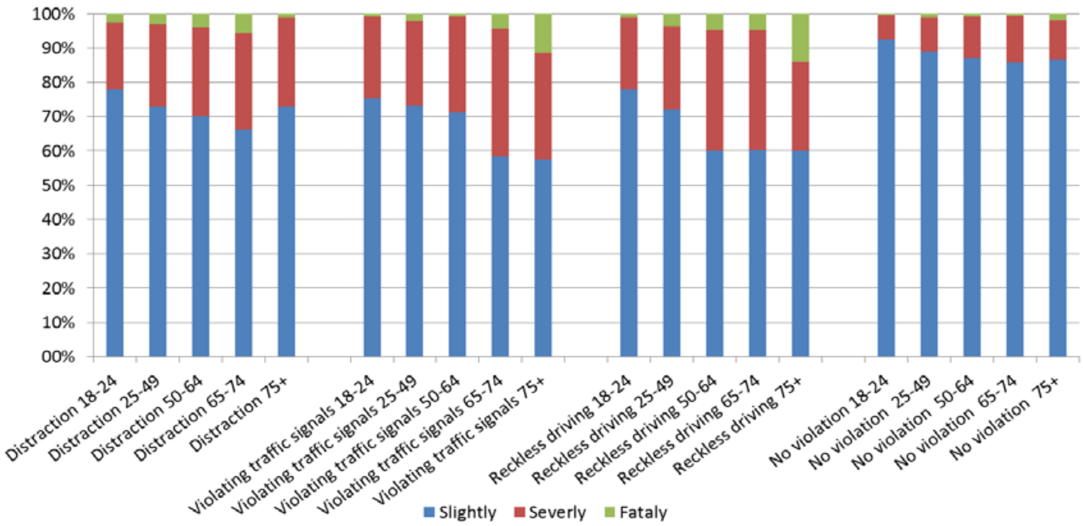


Figure 5.5 Consequences in terms of injury severity

5.1.3 Seating position and seat belt wearing

DGT database for Spain and GIDAS for Germany gave relevant information on the elderly seating position in crashes. At the study carried out with accidents database of Spain (DGT Microdatos de accidentes), the 90.6% of the sample (drivers or passengers) are in the front seating position (335,437 people) whereas the 9.4% (34,621 people) are in the back seating position. Considering all age ranges people involved in car accidents, men is seating in the front more often than women. The driver is a man 69.4% of times and is the passenger in the front 39.9% of times. Whereas, regarding the back position, the 53.8% times is a women (see Figure 5.6).

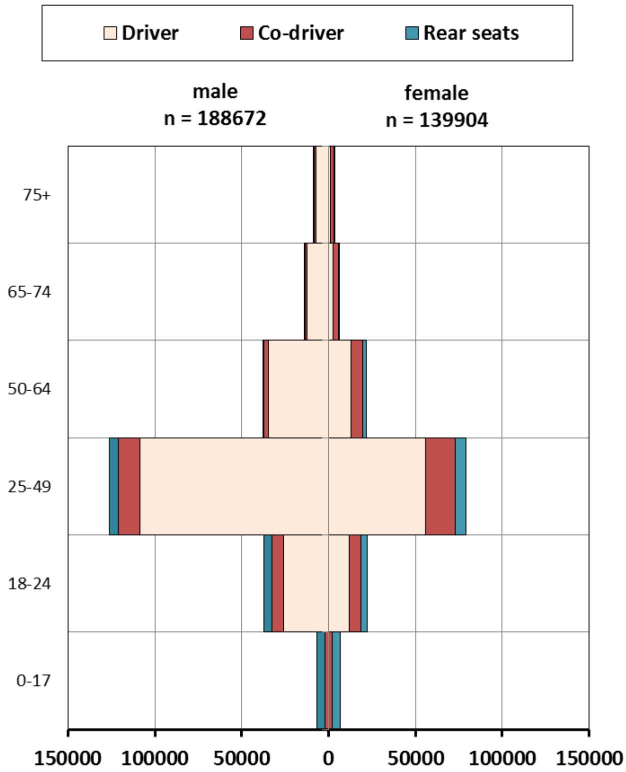


Figure 5.6 Behavior in car accidents: seating position, in Spain

In Germany (GIDAS) about the 95% of all seniors (drivers or passengers) are in the front seating position (n = 831 over 65 people) whereas the remaining 5% (n=38 over 65 people) are in the back seating position. Gender differences are relevant (see Table 5.1). Elderly drivers are 613 (over 12% of all drivers), of whom 79% are men, compared to women 21%; co-drivers are 218 (over 19% of all co-drivers), of whom 82% are women compared to men 18%.

Table 5.1 Seating position in GIDAS

Car Occupants in GIDAS for SENIORS excluding "unknown" (gender, age)		Seating Position									
		Driver		Co-Driver		2nd row		3rd row		all	
Gender	Age	n	%	n	%	n	%	n	%	n	%
FEMALE	0-24	217	39,5%	147	26,7%	182	33,1%	4	0,7%	550	100,0%
	25-64	1396	72,8%	422	22,0%	96	5,0%	4	0,2%	1918	100,0%
	65+	130	38,6%	179	53,1%	27	8,0%	1	0,3%	337	100,0%
subtotal FEMALE		1743	62,1%	748	26,7%	305	10,9%	9	0,3%	2805	100,0%
MALE	0-24	296	50,2%	129	21,9%	162	27,5%	3	0,5%	590	100,0%
	25-64	2395	88,5%	253	9,3%	57	2,1%	1	0,0%	2706	100,0%
	65+	483	90,8%	39	7,3%	10	1,9%	0	0,0%	532	100,0%
subtotal MALE		3174	82,9%	421	11,0%	229	6,0%	4	0,1%	3828	100,0%
Total		**4917**	**74,1%**	**1169**	**17,6%**	**534**	**8,1%**	**13**	**0,2%**	**6633**	**100,0%**

A clear difference to the European data shown above is displayed in CIREN database, for US context. The analysis showed that out of all the people involved in the car accidents the 83% of this sample (drivers or passengers) were in the front (1749 people) whereas the 17% (355 people) were in the back seating position. Considering the 2081 people involved in car accidents, the 40% of car occupants were men sitting in font position, the 44% of car occupants were women sitting in front position, the 9% were male sitting in back position and the remaining 7% were women sitting in back position. According age groups the 50.4% of seniors are female sitting in the front position instead the 44.2% are male sitting in the front position, as shown in Figure 5.7.

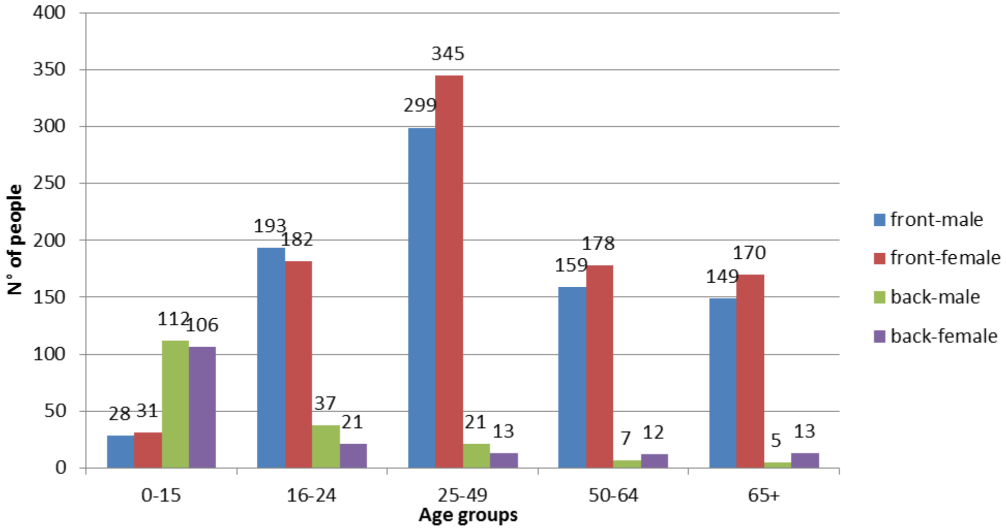
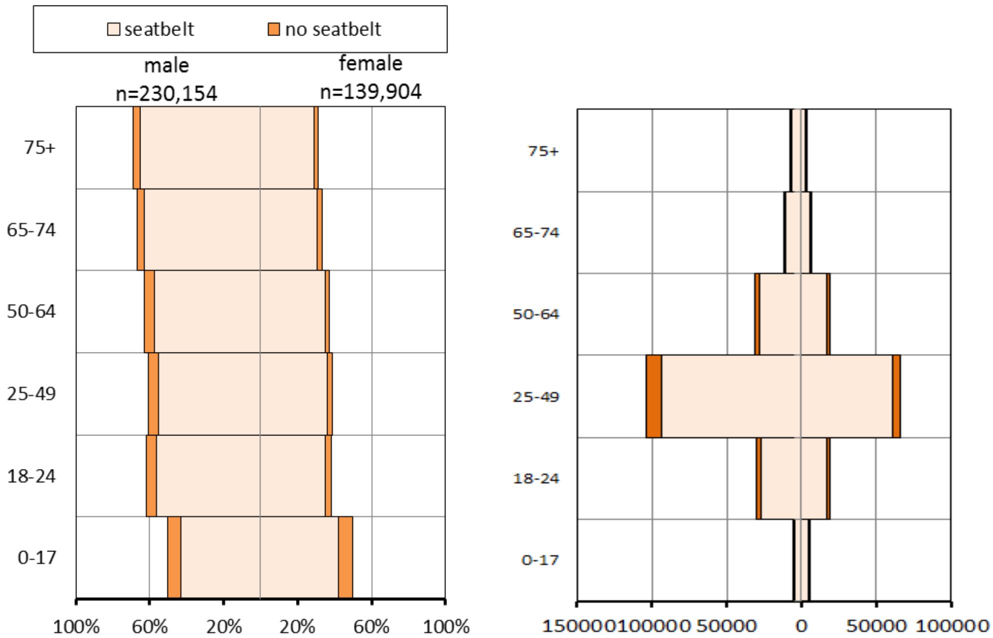


Figure 5.7 Seating position per gender and age groups, in USA

In Spain DGT database (DGT Microdatos de accidentes) provided information about seat belt wearing rates of drivers and passengers in a car involved in an accident. As shown in Figure 5.8, for each age range, the share of men involved in an accident is higher than women, except between 0 to 17 years old. The share of men involved in an accident and not wearing the seatbelt is higher at 18-24 years old age range and it is reduced with seniority. A similar trend can be observed with women. In general terms, women involved in accidents with victims use the seatbelt at 77.2% of cases and men at 74.5% of cases.



a) Share values of each age range b) Absolute values

Figure 5.8 Seat belt wearing rates of drivers and passengers in a car in Spain

Figure 5.9 shows that almost nine out of ten car occupants wore a seat belt, considering the figure below, with a decrease towards the rear seats.

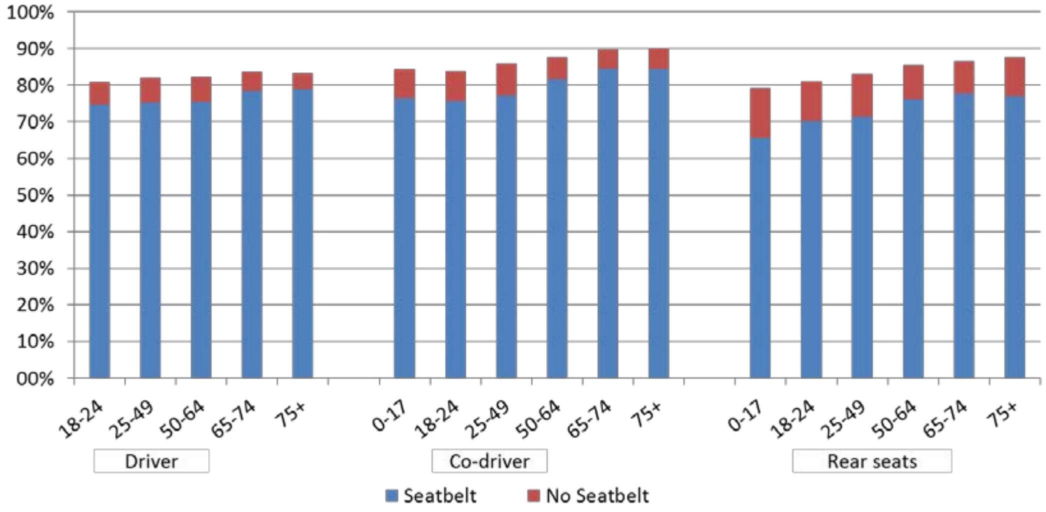


Figure 5.9 Percentage of seat belt wearing as drivers and/or passengers in Spain (the remaining percentage is unknown)

In Germany GIDAS database provided information about seat belt wearing rates of drivers and passengers in a car involved in an accident. As shown in Figure 5.10 about 97% of the elderly wore a seatbelt during the accident.

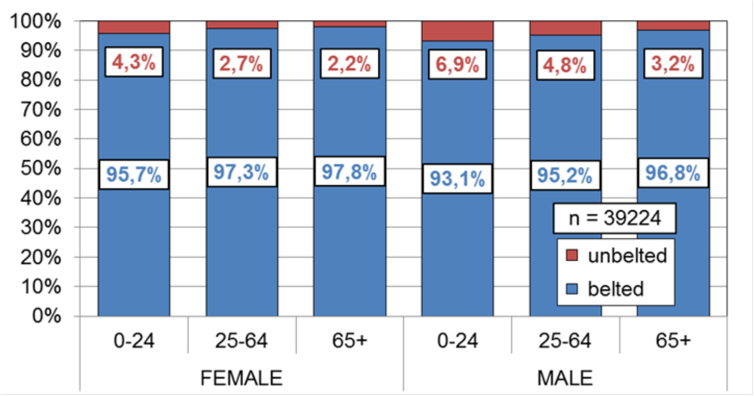


Figure 5.10 GIDAS database: seat belt wearing per age and gender

Quite similar are the US statistics. A sample of 2,055 people was investigated in the CIREN database. The 78% of this sample (1594 people) wore the seatbelt and, among these, the 85.5% sat in the front positions whereas the remainders in the back position.

Classification based on gender and age groups is inferable only for a sample of2,032 people involved in car accidents and the data are shown in Figure 5.11. The 46.4% of Over 65 are female sitting in front position and wearing the seatbelt, the 39.2 % are male sitting in front position and wearing the seatbelt.

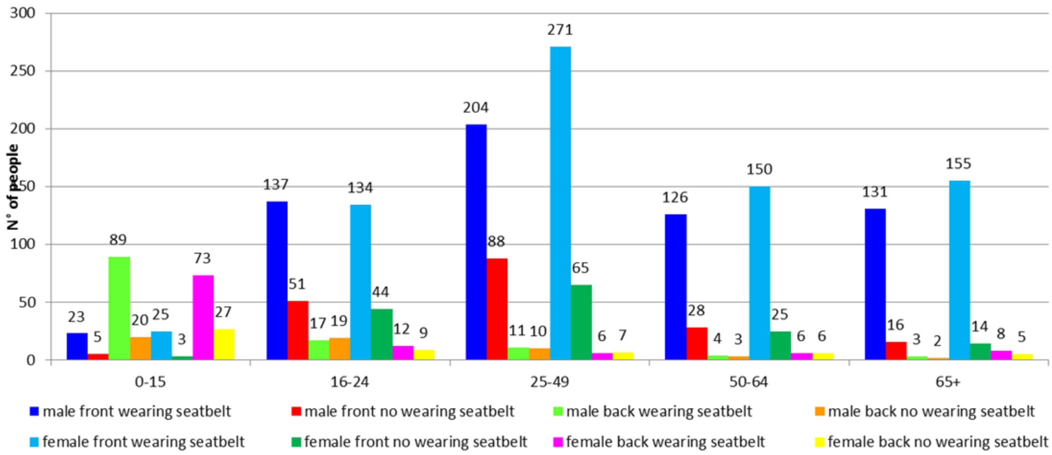


Figure 5.11 Seatbelt wearing per gender and age groups, in USA

In Germany, seat belt wearing rates of drivers and passengers in a car are gathered yearly through observations, but an exact attribution of the road users to age groups is not possible. Self-report data from ESRA showed that 81.0% of all German respondents aged 65 years and older reported that they had (almost) always worn a seat belt as a driver during the last 12 months. Within the overall population of the study, 79.2% of the respondents stated the like. With respect to being a passenger in the car, 94.7% of the interviewed seniors stated that they had (almost) always worn a seat belt as a passenger in the front of the car during the last 12 months. This rate represented the highest rate among all age groups. Within the overall population of the study, 77.2% of the respondents stated the like. The largest proportion of people who reported that they had (almost) always worn a seat belt in the back of the car was also found among the seniors. Within this group, 78.0% of all respondents stated this. In the overall study population, 71.8% of the interviewed persons reported that they had (almost) always worn a seatbelt as a passenger in the back of the car (calculations based on data from ESRA, 2015). Furthermore, a significant difference can be seen between certain age groups with respect to the attitude of respondents towards wearing a seatbelt in the front of the car. Even though the difference was small, persons aged 65 years and older personally found it less acceptable to not wear the seat belt in the front of the car than persons of all age groups between 18 and 44 years. No significant differences between the age groups were found with respect to the attitude towards wearing a seat belt in the back of the car (calculations based on data from ESRA, 2015).

Observations on seat belt usage were conducted by the Swedish National Road and Transport Research Institute (VTI) in a number of towns in Central Sweden since 1983 (Cedersund, 2002). The emphasis was on junctions with high traffic volumes, including both local and long-distance traffic. Similarly a sub-project started looking at seat belt use by age and gender. From 1983-1988 seat belt usage continuously increased (greatest increase being for rear seat passengers) reaching 74% by 2001 (for adults) and 90% for children in the rear seat. For front seat passengers it's between 90-92%. It was also found that 93% and 98% of male and female drivers 50 years and older wore the seat belt, respectively.

Similarly the survey conducted by Department for Transport England and Transport Scotland (2015) about the usage of seat belt revealed that about the totality of all drivers (95.3%) were observed using seat belts in England and Scotland; they are split as follows: the 94.6%of all front seat passengers were observed using seat belts or child restraints, similarly the 90.3% of all rear seat passengers were observed using seat belts or child restraints. It appears that the proportion of adult car rear seat passengers wearing a seat belt has increased steadily from 54% in 1999 to 81% in 2014. The difference between males and females was lower for male drivers in England and Scotland who had a lower seat belt wearing rate (93.7%) than female drivers (98.2%). About age it appears that seat belt wearing rates were higher for drivers aged 17-29 and aged 60 years and over (96.1% and 96.5%) with seat belt wearing rates for drivers aged 30-59 lower at 94.7%. For car drivers, seat belt use increased with age with a higher proportion of car drivers aged 60 years and over observed wearing a seat belt (98.8%) than those aged 17-29 (97.4%) and 30-59 (98.2%). Overall restraint wearing rates for male and female front seat passengers in England and Scotland were lower than for male and female drivers. They are split as follows:

- Male front seat car passengers in England and Scotland had a lower restraint wearing rate (95.7%) than female front seat car passengers (97.5%).
- For car front seat passengers in England and Scotland, the age group with the lowest restraint wearing rates were aged 0-13 (93.3%).
- Car front seat passengers aged 14-29 (94.4%), 30-59 (97.6%) and 60 & over (98.3%) had higher rates.

Overall restraint wearing rates for male and female rear seat passengers in England and Scotland were lower than for male and female front seat passengers and drivers. They are split as follows:

- Male rear seat car passengers in England and Scotland had a lower restraint wearing rate (88.3%) than female rear seat car passengers (91.3%).
- For car rear seat passengers in England and Scotland, the age group with the lowest restraint wearing rate was aged 14-29 (82.7%); 30-59 (89.1%) and 60 & over (92%) had higher rates.

As stated above, it seems that senior car occupants use seat belts more often than any other age group, but there are still some who never or only sometimes use it.

Further research activities have been developed to identify the reasons for choosing not to use the seat belt whereby one reason might be discomfort.

In an observational study recently conducted in Australia seat belt fit as well as its association with body shape were examined among drivers aged 75 years and older. When looking at the lap belt and sash belt fit, the researchers found that good fit was achieved in 53% and 59% of all cases, respectively. The sash often passed too close to the neck or the tip of the shoulder. Poor lab belt fit always involved the belt being positioned too high, over the soft abdomen. Only 35% of the elderly demonstrated good overall belt fit. With respect to the body shape, the odds of having a poor lap belt fit were higher for seniors with high Body Mass Index. Furthermore, 5% of the seniors reported at least sometimes positioning the sash under their arm or behind their back. These results suggest a fairly high rate of seat belt fit problems in the elderly population. A mis-positioned seat belt may negatively influence the distribution of loads applied to the torso during a crash and may therefore increase the risk of injury to chest and abdomen (Fong, Keay, Coxon, Clarke, Brown, 2016).

The researchers furthermore examined rates of seat belt repositioning as well as the use of add-on accessory among Australian drivers aged 75 years and older. Of the surveyed seniors, 20% reported repositioning the seat belt to improve comfort. 32% of the respondents did not know if their sash was height adjustable and 30% reported not having this feature in their car. Of the elderly drivers who stated to have such a feature in their vehicle only 59% reported having adjusted the height for better fit or comfort. Observations of the older drivers in their own vehicles showed that seat belt comfort pads were used by 9% and seat accessories by 17% of the elderly drivers. The different seat accessories included seat base cushions, seat back cushions, back support or head-rest cushions. Seat belt pads were more likely to be used by shorter drivers, while a seat accessory was more likely to be used by elderly who reported seat belt discomfort. In conclusion, the study points out that a significant proportion of elderly drivers try to improve the match between their body and the seat belt fit/ comfort by using seat accessories. Up to date the impact that such accessories have on crash protection is still insufficiently studied (Coxon, Keay, Fong, Clarke, Brown, 2014).

The CIREN database was also investigated with respect to the adjustment of seat belts and the usage of cushions. About the “adjustment of seatbelt”, on a sample of 2,036 occupants, the 68% of this sample (1,375 people) adjusted the seatbelt; among the remaining 32%, no adjustments of seatbelt were detected. No relevant gender distinction was found.

Classification based on gender and age groups was inferable only for a sample of 2,016 people involved in car accidents and the data are shown in Figure 5.12. The 42.5% of Over 65 are female with adjustments of seatbelt, the 37.1% are male with adjustments of seatbelt.

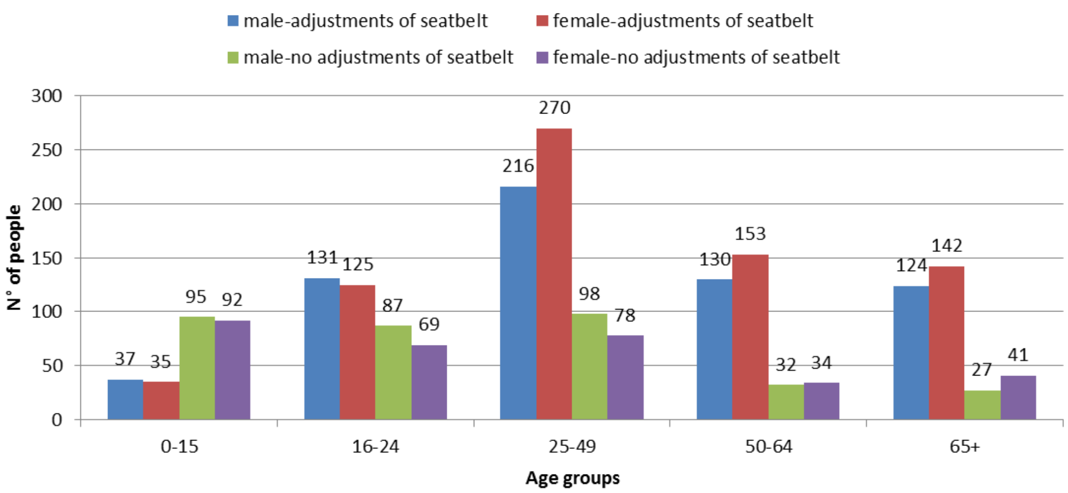


Figure 5.12 Adjustments of seatbelt per gender and age groups, CIREN

In the same database, moreover only the 5% of this sample (112 car occupants) uses cushions and, among these, nearly the 64% are men. Classification based on gender and age groups was inferable only for a sample of 2,044 people involved in car accidents and the data are shown in Figure 5.13 the 52.5% of Over 65 are female with no usage of cushions; the 40.9% are female with usage of cushions.

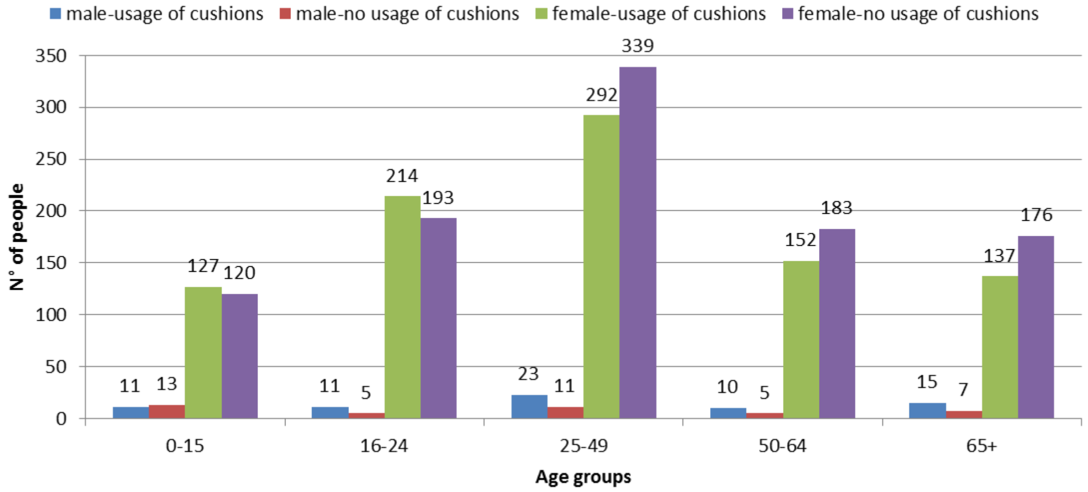


Figure 5.13 Usage of cushions per gender and age group, CIREN

5.1.4 Behaviour as driver

The low numbers of accidents due to behaviour such as speeding, overtaking, and alcohol point to a rather risk-aversive behaviour of senior car drivers though, an assumption that is further supported by self-report data. As part of the fourth implementation of the SARTRE interviews it was shown that with respect to the consumption of alcohol 77.8% of interviewed German respondents 65 years and older reported that they had never driven a car after drinking even a small amount of alcohol over the last month. This constituted the highest proportion in all age groups. Within the overall population of the study, 66.5% of all respondents stated the like (calculations based on data from SARTRE4, 2013). Driving after the consumption of alcohol above the legal limit was even more seldom in the group of the seniors. Here, 96.6% of the senior respondents reported they had never driven under those circumstances in the last month. Within the overall population 90.4% stated the like. Over all 19 European countries in which the interviews were conducted, 85% of surveyed car drivers reported not having driven after drinking over the legal limit in the past month. The pattern in the participating countries shows that being drunk over the legal limit and driving decreases with age. The odds of drink driving over the legal limit decrease by 23% for drivers 65 years and older compared to drivers aged 17 to 24 years (Bimpeh, Brosnan, Schmidt, Miklós, 2012). With respect to the opinion about what the legal limit of alcohol should be for drivers, a zero tolerance was supported by 60.2% of the respondents over 65 years. This constituted the highest proportion in all age groups. Within the overall study population 49.8% of respondents stated that drivers should not be allowed to drink any alcohol before driving (calculations based on data from SARTRE 4, 2013). Similar results were found in the European Survey of Road User's Safety Attitudes (ESRA). Over all 17 European countries in which the ESRA survey was conducted, the acceptability of driving after having consumed alcohol was lower in the oldest age group (55 years and older). Furthermore, the proportion of people who perceived impaired driving as increasing the risk of an accident was higher among the oldest age group (Achermann Stürmer, 2016).

With respect to speeding, 74.7% of German respondents 65 years and older reported on ESRA that in the past 12 months they had rarely or never driven faster than the speed limit allowed inside built-up areas. This constituted the highest rate among all age groups. Within the overall population of the study, 60.9% of all respondents stated the like. Furthermore, 88.8% of the surveyed seniors stated that they believe it is rather or completely inacceptable for a driver to drive 20 km/h over the speed limit in an urban area. This again represents the highest proportion among all age groups. Within the overall population, 78.7% shared this opinion (calculations based on data from ESRA, 2015). Over all 17 European countries in which the ESRA survey was conducted, the acceptability of speeding behaviours was lower for older people (55 years and over) compared to younger age categories and age was generally associated with a decrease in the tendency to violate the speed limit (Yannis, Laiou, Theofilatos, Dragomanovits, 2016).

Even though the prevalence of senior driver's engagement in distracting activities is largely unexplored in Germany, self-report data collected in face-to-face interviews subsequent to trips suggest that older drivers are less likely to engage in such activities than middle-aged drivers. They furthermore rated most of the distracting activities as significantly more dangerous than their middle-aged counterparts (Fofanova & Vollrath, 2012). As part of the ESRA survey, 92.5% of German respondents 65 years and older reported that in the past 12 months they had rarely or never talked on a hand-held mobile phone while driving. This constitutes the highest proportion among all age groups. Within the overall population of the study, 79.3% of all respondents stated the like. Similar results can be found with respect to reading and sending text messages or e-mails. 96% of the senior respondents reported that in the past 12 months they had rarely or never read a text message or an e-mail when they were driving which again represents the highest rate among all age groups. In the overall population, about 81% of all respondents stated the like. Over all 17 European countries in which the ESRA survey was conducted the frequency of having used a mobile phone while driving at least once in the past 12 months decreased with age (Trigoso, Areal, Pires, 2016). With respect to the attitude towards the use of any type of mobile phone while driving, a zero tolerance was supported by 55.4% of the German respondents 65 years and older (calculations based on data from ESRA, 2015). Over all 17 European countries, the acceptability of talking on a mobile phone or texting while driving decreased with age. Furthermore, it was found that the perception of the negative effects of talking on a mobile phone while driving increased with increasing age (Trigoso et al., 2016). Since self-report data are prone to response bias, objective data from behavioural observations or naturalistic driving studies is needed to gain a better understanding of the prevalence and effects of distraction among senior drivers in Germany. In 2014 the Department for Transport and Transport Scotland commissioned mobile phone and seat belt surveys to monitor levels of mobile phone use by drivers and the use of seat belts by vehicle occupants across England and Scotland (Department for Transport and Transport Scotland, 2015). The survey showed that 1.6% of drivers in England and Scotland were observed using a handheld mobile phone (i.e. a device that is being held at the time of observation) whilst driving. The majority of these drivers were using a phone in their hand rather than holding it to their ear; 1.1% of drivers in England and Scotland were observed holding a phone in their hand compared with 0.5% observed holding the phone to their ear. This suggests that most mobile phone usage whilst driving was for the purposes of sending or receiving a text or using social media rather than making a call. A significantly higher proportion of male drivers were observed using hand-held mobile phones than female drivers; 1.5% of male drivers in England and Scotland were observed using a hand-held mobile phone compared with 1.3% of female drivers. In particular:

- 1.2% of male drivers were observed using a phone in their hand compared to 0.5% observed using a phone held to their ear.
- 0.9% of female drivers were observed using a phone in their hand compared with 0.4% observed using a phone held to their ear.

A similar proportion of drivers in England and Scotland were observed using a hand-held mobile phone on urban roads (1.7%) compared with 1.4% on rural roads.

About age a higher proportion of 17 to 29 year old drivers in England and Scotland were observed using hand-held mobile phones (5.2%) than both 30 to 59 year old drivers (2.4%) and drivers aged 60 and over (0.7%). Drivers were less likely to use a hand-held mobile phone if they had passengers present in their vehicles; 2.7% of drivers in England and Scotland without passengers present in their vehicles were observed using a hand-held mobile phone compared to 1.2% of drivers with passengers present in their vehicle.

Parr et al. (2016) studied personality traits because they may be important predictors of distracted driving behaviours in both teens and older adults. The relationship between personality and distracted driving behaviours provides a unique opportunity to target drivers who are more likely to engage in distracted driving behaviour. In particular it was found that in older adults, greater extraversion was predictive of greater reported talking on and interacting with a phone while driving.

Furthermore the study carried out with Spain DGT accident data (DGT Microdatos de accidents) shows that common accident causes in Spain, among the elderly behaviour, are about distraction, violation of traffic signals and reckless driving, such as insufficient safety distance, take up part of the opposite direction lane or zig-zag driving (see Figure 5.14). It shows the proportion of accidents caused because of distraction is lower for middle age drivers and increases with seniority up to a 20% of cases while the driver is older than 75. Violating traffic signals is also a more common cause of accident for senior drivers. Driving errors is a common cause of accident for youngest drivers, it supposes more than 5% of young driver accidents, but it is also common for the oldest drivers, probably because poor reflexes of a lack of attention. This matches with previous explained studies.

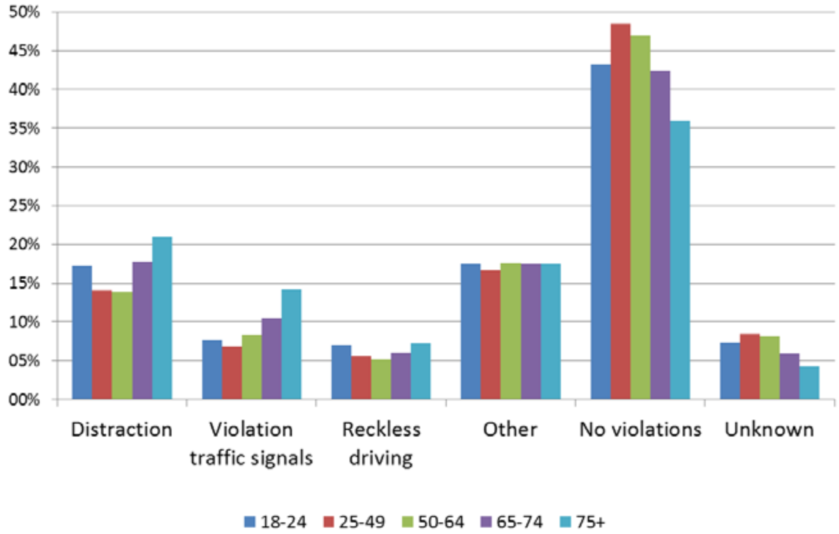


Figure 5.14 Other common law violation in Spain

Also, the inadequate speed as a cause of accidents is quite common for youngers but it decreases with seniority (see Figure 5.15).

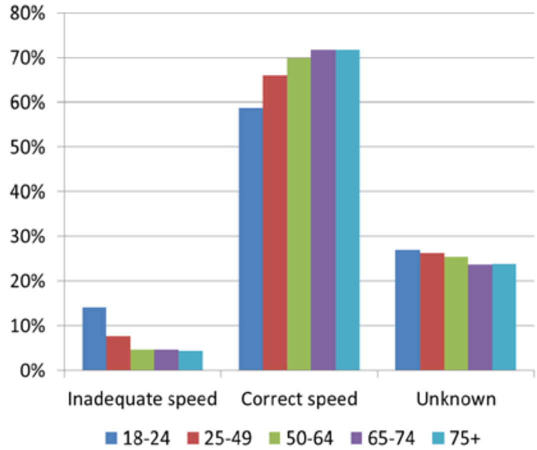


Figure 5.15 Inadequate speed in Spain

5.2 ELDERLY AS CYCLISTS

In the following sections the crash involvement of elderly cyclists, typical accident scenarios and safety behaviour will be described.

5.2.1 Crash involvement of elderly cyclists

Cyclists make up 8% of all fatalities on European roads (European Commission, 2015 b). The number of cyclist fatalities has decreased by 3% which is much lower than the total fatality decrease of 18% from 2010 to 2013. One possible reason for the slow reduction of the number of cyclist casualties is that the total number of cyclists goes up in the EU as more people turn to more sustainable and healthy transport modes. Cyclists suffer fatal and serious injuries on both urban and inter-urban roads. Of all cyclist fatalities, 57% were killed in urban areas.

An European research (European Commission, 2015 b) points out that among the cyclists killed in road traffic crashes, 21% were women. The age profile shows that children and young people are comparably safe. Cyclists younger than 25 years make up around a tenth of all cyclist road deaths. Figure 5.16 shows that the elderly are over-represented, 42% of all killed cyclists were 65 years or older.

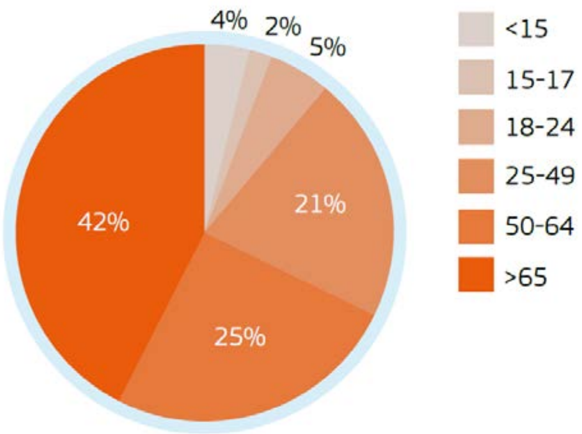


Figure 5.16 Cyclist fatalities per age group

In Germany, transport performance was assessed in 2008 as part of the survey Mobility in Germany (infas & DLR, 2010). Drawing on accident rates reported in the respective year, it is possible to calculate crash rates per kilometre travelled. As can be seen in Figure 5.17, the highest rate of injured or killed cyclists was found among the 18- to 29-year-olds. With increasing age the number dropped and remained relatively low for persons between 30 and 69 years of age. From an age of 70 years, the rate of injured or killed cyclists started to climb again and reached for seniors aged 75 years and older the highest rate among all age groups (calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010).

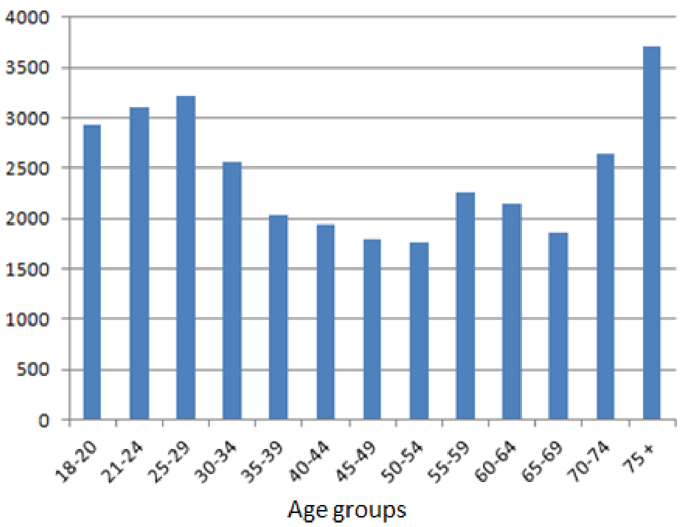


Figure 5.17 Number of injured or killed cyclists of different age groups per 1 billion kilometers traveled

These high rates among the elderly were mainly due to a high number of fatalities among senior cyclists. When solely depicting the fatalities, as shown in Figure 5.18

(calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010), the numbers are relatively low for young cyclists, gradually increase with age and rise strongly for persons 70 years and older. The primary cause for this high fatality rate is the increased frailty of the elderly.

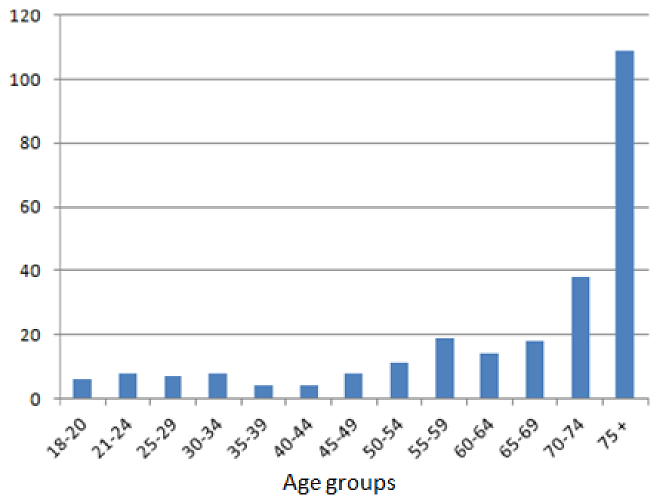


Figure 5.18 Number of killed cyclists of different age groups per 1 billion kilometers traveled

5.2.2 Typical accident scenarios of elderly cyclists

Information on the characteristics of the accidents in which senior cyclists got injured or killed in Germany can be taken from a recent representative study by von Below (2016), who complemented accident descriptions of cyclists with data on injury and treatment provided by hospitals. With respect to the kind of accident, a single-bicycle crash was the most common of all registered crashes among elderly cyclists. 41.7% of all accident situations could be classified as such. In 9.7% and 8.8% of all cases, a collision with a car and another cyclist occurred, respectively. A collision with an obstacle, a truck, and a pedestrian was reported in 3.9%, 1.2%, and 1.2% of all accidents of senior cyclists, respectively (calculations based on data from von Below, 2016).

As cause of the accident, 14.1% of the involved senior cyclists reported a poor surface, 13.1% reported loosing balance, and 11.1% reported not having seen the obstacle. In 9.4% of all accidents the other party was rated as having caused the crash. Distraction was only mentioned by 2.5% of all accident-involved senior cyclists (calculations based on data from von Below, 2016).

Studying the Spanish database (DGT Microdiatos de accidents), it can be seen that main accidents take place following the route for all age ranges, however turning or crossing accidents are a common accident scenario for young and senor cyclists. Cyclists between 65 and 74 years old have an accident when crossing or turning at 15% of times and it happens nearly to 25% of cases when the cyclist has 75 or more (see Figure 5.19).

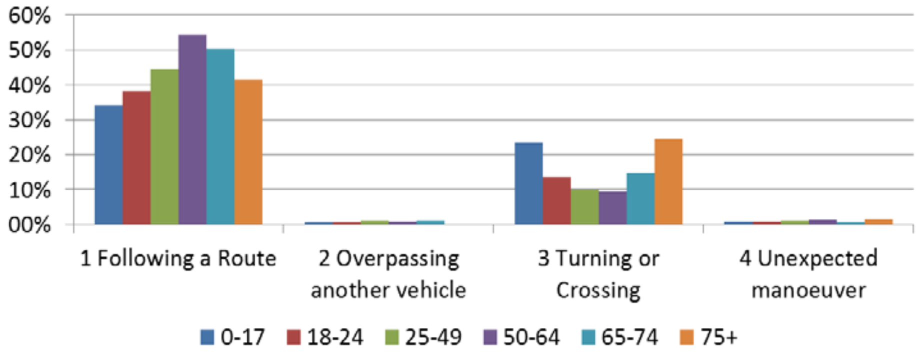


Figure 5.19 Actions with more frequent accidents associated, in Spain

5.2.3 Safety clothing

In Germany in a recent representative survey among cyclists, only 17.2% of respondents 65 years and older stated to always wear a helmet when riding their bicycle. In the overall population 21.4% reported the like. Never wearing a helmet was stated by 72.3% of all senior cyclists which constituted the highest proportion among all age groups. If the elderly decide to wear a helmet, it is mainly on longer bike rides, busy roads, in the open country or when riding with a group of people. Furthermore, 62.4% of seniors stated that they make sure to wear clothing that is clearly visible when riding their bike. 93.3% of senior cyclists also stated that they had never (74.7%) or rarely (18.6%) ridden their bike without sturdy shoes. In the overall population this was reported by 49.6% and 30.3%, respectively (calculations based on data from von Below, 2016).

Also the GIDAS data confirmed that overall German people didn't wear helmet, with more emphasis to the female elderly cyclists (only 1.6%) In Figure 5.20, rates of helmet usage are shown, according to age and gender.

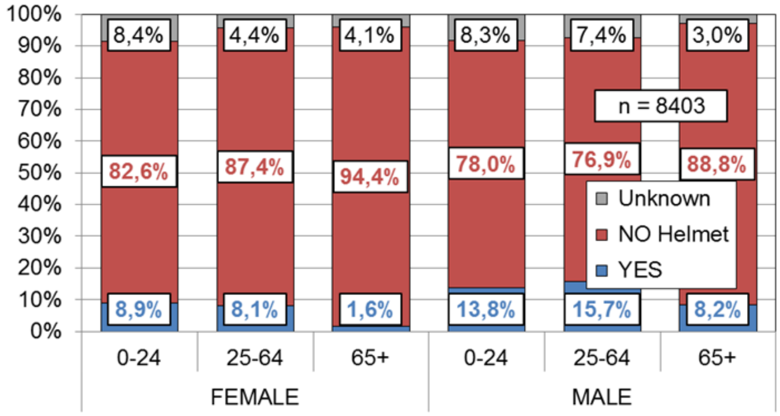


Figure 5.20 Use of helmet in Germany according age and gender

Helmet is frequently worn by Spanish cyclists. Figure 5.21 shows that in Spain men use helmets more frequently than women do. Of all the registered cases of bicycle accidents, there were more cases involving male cyclists than female and men also used helmets more regularly. Probably that is because men use to cycle more than women on interurban roads for doing sports.

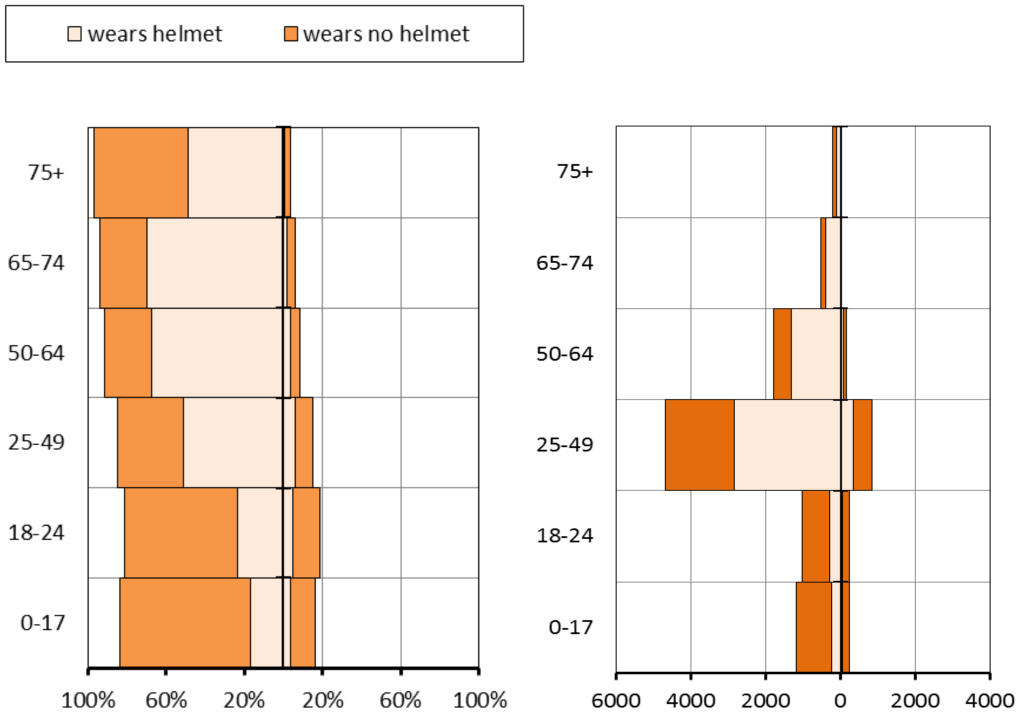


Figure 5.21 Use of helmet when cycling in Spain

Moreover Figure 5.22 shows the distribution of cyclists involved in a crash wearing a helmet or not. Among the age class 65-74, most of the people wears helmet, while among the age group of 75 and older the percentage of cyclists involved in a crash wearing helmet is only the 35%. The younger show a high percentage of not wearing helmet when involved in a crash.

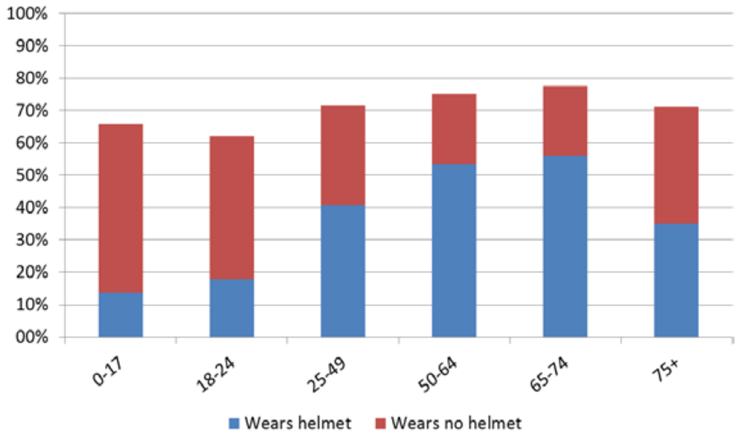


Figure 5.22 Cyclists involved in a crash wearing or not helmet in Spain (remaining percentages are unknown)

The International Transport Forum Road Safety Annual Report (ITF, 2013) showed that among the countries reported on, the number of cyclist fatalities decreased by 53% between 1990 and 2011 in countries with helmet law. In countries without a helmet law, the rate only decreased by 45%.

5.2.4 Behaviour as cyclist

As part of a recent representative survey (von Below, 2016), German cyclists were asked about having been given warnings by the police for traffic violations. Of the respondents aged 65 years and older, 14.1% had received such a warning as a cyclist within the last two to three years. Within the overall population, 23.6% reported the like. The most common violation was riding the bicycle on the sidewalk, for which 7.7% of the surveyed seniors had been given a warning. Furthermore, riding the bicycle in opposite direction of traffic, running a red light, and disregarding the right of way lead to warnings for 2.7%, 2.0%, and 1.7% of the surveyed elderly, respectively. Reports of warnings being issued due to speeding, talking on the phone, riding in the dark without lights, and alcohol were even less common (calculations based on data from von Below, 2016). A comparison across age groups showed that elderly cyclists report the least amount of issued warnings. This suggests a greater conformity to traffic laws, but it needs to be noted that these statistics are based on self-report data and are therefore prone to bias.

When asked about the frequency of riding their bike after having consumed alcohol, 95.6% of seniors stated that they had never (71.5%) or rarely (24.1%) ridden their bike after having consumed alcohol. Within the overall population, the same was stated by 61.1% and 31.5%, respectively.

With respect to riding the bike in the dark without headlights on, 97.0% of seniors stated that they had never (74.7%) or rarely (22.3%) done so before. Within the overall population, the same was stated by 59.0% and 31.1%, respectively.

An even greater difference between the age groups can be found with respect to having talked on the phone while riding a bicycle. 98.3% of seniors stated that they had never (93.6%) or rarely (4.7%) talked on the phone while riding their bike. In the overall population, 64.7% and 23.7% stated the like (calculations based on data from von Below, 2016).

As part of a survey by Hagemeister and Tegen-Klebingat (2011) among German cyclists between the age of 60 and 90 years, among others the engagement in secondary tasks while cycling was examined. Of the surveyed seniors, 41% reported to observe their luggage when cycling and 36% stated to make use of other items (e.g., tissues) Furthermore, 36% reported to talk to people and 30% stated to reach out to grasp their luggage.

Luggage transport on the bicycle rack was reported by 64% of the elderly cyclists. 53% and 51% stated transporting their luggage in a backpack on their back and in a basket on the bicycle rack, respectively. 28% reported hanging their bags over the handlebar of the bike while 24% stated transporting it in a handlebar bag.

Turning without indicating the intention to do so by hand signal was reported less frequently among the elderly. Having never (17.7%) or rarely (43.5%) done so was stated by 61.2% of respondents 65 years and older. In the overall population 13.2% and 36.2% reported the like. Furthermore, of the senior cyclists 89.5% stated that they had never (60.8%) or rarely (28.7%) run a stop sign. In the overall population, the same was reported by 42.9% and 34.0%, respectively (calculations based on data from von Below, 2016).

In Germany 82.6% of elderly cyclists indicated that there are certain weather conditions or times of the day where they do not ride their bike. Out of all the reasons, snow and black ice were mentioned most often, followed by rain, coldness, as well as strong wind (calculation based on data from von Below, 2016).

The aforementioned information provides a first description of the behavior of the senior population of German cyclists. It needs to be noted though that they are mainly based on self-report data and in future research activities have to be complemented by objective (observational) measurements.

Analysing Spain data (DGT Minidatos de accidentes), it can be observed that main part of accidents take place when cyclists are driving properly. Regarding senior cyclists, they use to have more accidents because of violating traffic signals (11% of cases) than younger cyclists, probably because poor reflexes of a lack of attention. These match with previous explained studies (see Figure 5.23). The tendency is similar to car driver behaviour described at point 5.1 of this document.

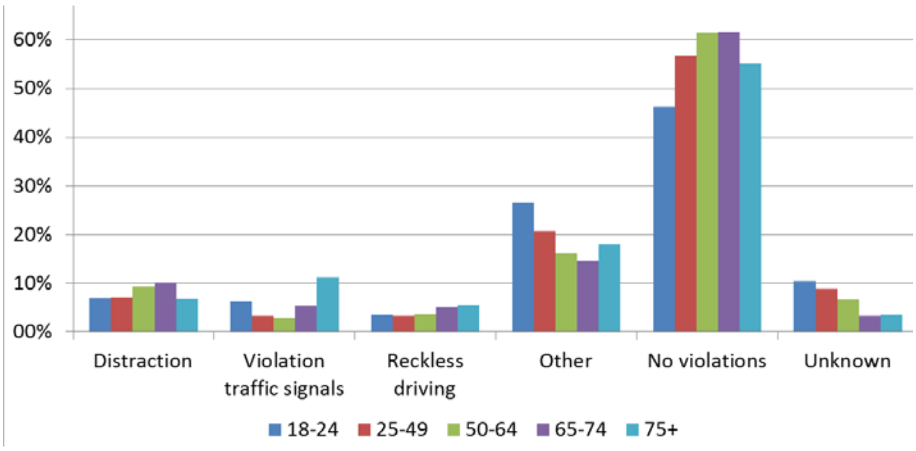


Figure 5.23 Common law violation accident causes in Spain

Cause accident regarding inadequate speed is low at all ages and it decreases with seniority (see Figure 5.24).

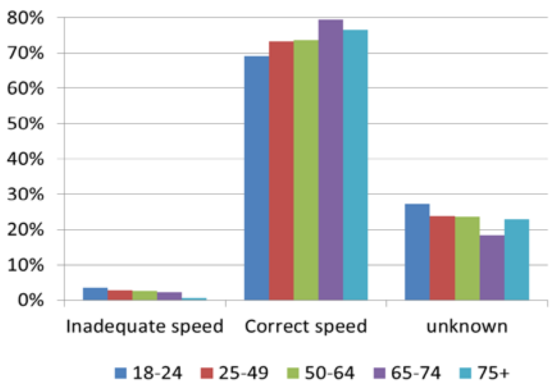


Figure 5.24 Inadequate speed in Spain

5.3 ELDERLY AS PEDESTRIANS

In the following sections the crash involvement of elderly pedestrians, typical accident scenarios, safety behaviour, and injuries will be described.

5.3.1 Crash involvement of elderly pedestrians

In 2013, the 22% of all who died in road traffic crashes were pedestrians. The number of pedestrians killed on roads in the EU has decreased by 11%, compared to the total fatality decrease of 18% from 2010 to 2013. The share of elderly is also higher among the pedestrian fatalities than among the total road deaths. Around 44% of all killed pedestrians were 65 years or older (see Figure 5.25). The 15-24 year olds make up only 8% of the pedestrian fatalities (European Commission, 2015 b).

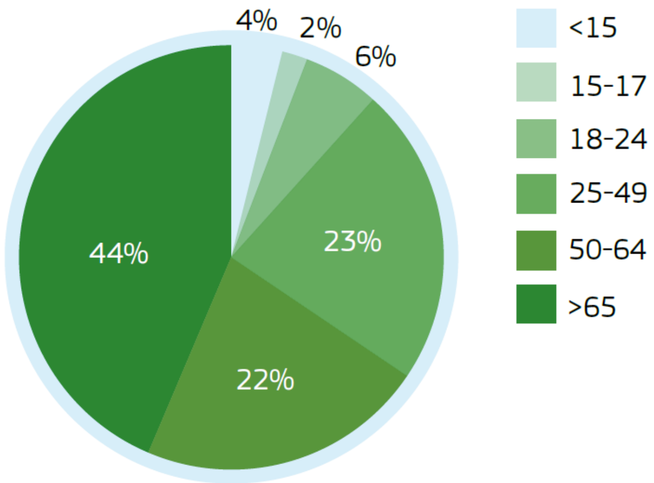


Figure 5.25 Pedestrian fatalities per age group

In Germany, transport performance was assessed in 2008 as part of the survey Mobility in Germany (infas & DLR, 2010). Drawing on accident rates reported in the respective year, it is possible to calculate crash rates per kilometre walked. As can be seen in Figure 5.26 (calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010), the highest rate of injured or killed pedestrians was found among the 18- to 20-year-olds. With increasing age the rate dropped and remained relatively low for pedestrians aged 35 to 69 years old. From an age of 70 years, the number of injured or killed pedestrians started to climb again reaching for seniors aged 75 years and older a rate comparable to that of people in their mid-20s (calculations based on data from Federal Statistical Office of Germany and infas & DLR, 2010).

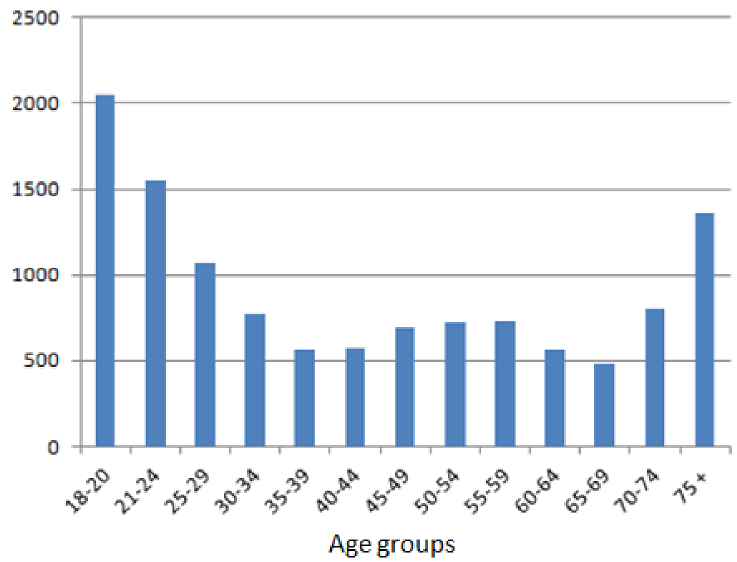


Figure 5.26 Number of injured or killed pedestrians of different age groups per 1 billion kilometers walked

When solely depicting the fatalities, as shown in Figure 5.27 (Federal Statistical Office of Germany and infas & DLR, 2010), it can be seen that a large proportion of pedestrians who decease due to road accidents were over the age of 65 years. The highest rate could be found for persons 75 years and older. The primary cause for this high fatality rate among the elderly is their increased frailty. They suffer greater injuries in crashes of the same intensity when compared to younger road users.

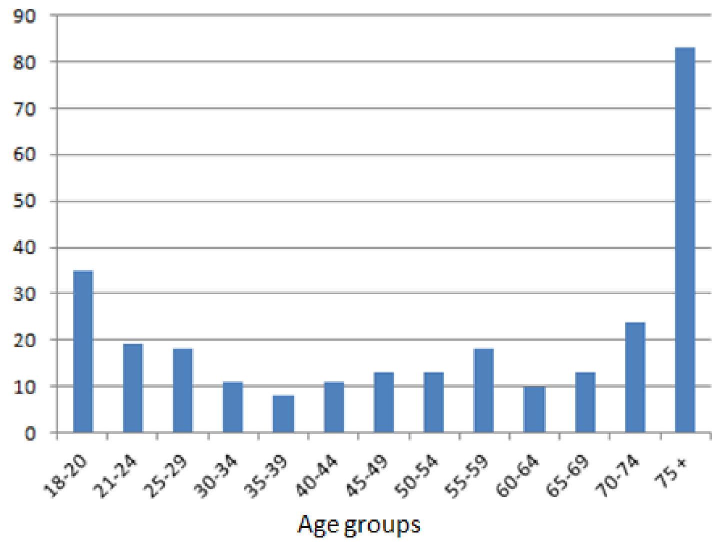


Figure 5.27 Number of killed pedestrians of different age groups per 1 billion kilometers walked

5.3.2 Typical accident scenarios of elderly pedestrians

With respect to the location of accidents of pedestrians, German statistics show that 96.5% happen in urban areas, 3.3% out of town, and 0.2% on motorways (calculations based on data from Federal Statistical Office of Germany, 2015). An analysis of accident report forms showed that 16% of accidents happened on intersections. 7% of accidents were each recorded to have happened on driveways and inclines. Furthermore, 4% happened on turns in the road. For the remaining cases no information was provided (Ellinghaus & Steinbrecher, 1992).

Lapses of pedestrians 65 years and older in accidents with personal injuries were in 80.0% of cases classified as inaccurate behaviour when crossing a road. In two out of three of these cases the elderly pedestrian failed to check for oncoming traffic. Furthermore, 2.2% and 2.0% of lapses were due to physical and mental deficits as well as alcohol, respectively. Not using the sidewalk and not walking on the designated side of the street were registered as mistakes in 2.2% and 0.5% of all cases, respectively (calculations based on data from Federal Statistical Office of Germany, 2015).

It is furthermore suggested that compared to the middle-aged, older pedestrian fatalities are overrepresented in single-pedestrian accidents as a result of falling (Polders et al., 2015). Since falls are often unreported, there is little data on their magnitude and consequences (Feypell, Methorst, Hughes, 2012). A study conducted in the Netherlands in 2009 revealed that around 80% of pedestrian injuries and one third of pedestrian fatalities across all age groups were due to falls (Methorst, Essen, Ormel, Schepers, 2010).

With reference to accident data the Spanish DGT Study covers the percentages of pedestrians accidents related to the circumstances (see Figure 5.28). Frequently, pedestrian accidents occurred when they were crossing inappropriately a road followed by when they were walking on the road. It can be observed that most of the accidents occurred were non-violation related – for people over 75 years, these are 65% of all cases. This is followed by 17% of cases, when people over 75 were crossing road, when there was no pedestrian crossing or traffic light was red, called crossing inappropriate.

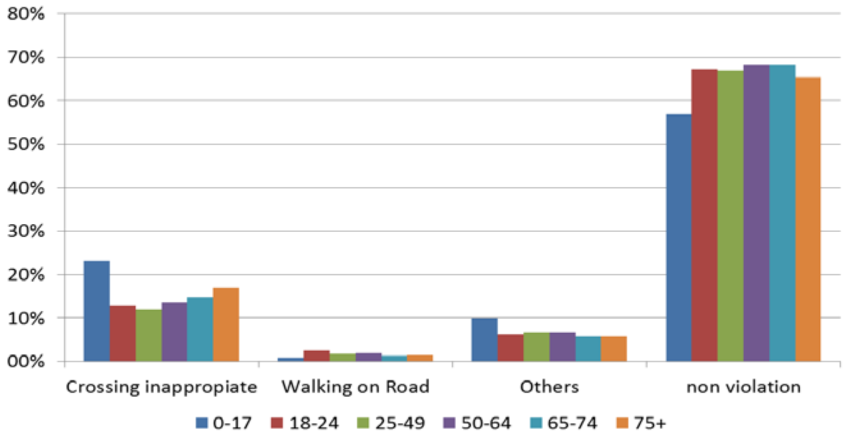


Figure 5.28 Pedestrians circumstances of the accidents

5.3.3 Behaviour as pedestrian

With respect to the behaviour of elderly pedestrians, different activities, e.g., walking, and street crossing have been analysed. One typical observation is a decrease in walking speed and acceleration capacity with increasing age (Asher, Aresu, Falaschetti, Mindell, 2012; Buckley, Pitsikoulis, Barthelemy, Hass, 2009; Dommes, Cavallo, Dubuisson, Tournier, Vienne, 2014).

Bernhoft and Carstensen (2008), with support of a questionnaire, compared behaviour of older pedestrians (women and men, 70 years and above) to a group of people aged 40–49. The older respondents appreciated pedestrian crossings, signalized intersections and cycle paths significantly more than the younger respondents do. To a larger extent they felt that it is dangerous to cross the road where these facilities are missing. The older pedestrians also found the presence of a pavement very important on their route, whereas the younger pedestrians more often focus on a fast passage. Differences in preferences and behaviour within the group of older respondents were related to differences in health and physical abilities rather than to differences in age and gender (Bernhoft & Carstensen, 2008).

It has also been shown that a certain amount of traffic-light-controlled pedestrian crossings do not permit the elderly enough time for safe clearance of the road (Bollard & Fleming, 2013). With respect to walking, shorter stride lengths, greater standing widths, a bent posture as well as more time spent on the double support phase (i.e., both feet on the ground) have been found among the elderly (Salzman, 2010; Winter et al., 1990). Older pedestrians spend more time looking at the ground and less at the other side of the street to cross. Watching their steps might lead them to be less attentive to traffic (Avineri, Shinar, Susilo, 2012; Zito et al., 2015).

With respect to selecting an adequate location to cross a road, even though elderly pedestrians compared to younger ones prefer using pedestrian crosswalks and intersections with signals, the majority of them reports regularly crossing the street at their current position, especially when visibility is good or traffic is sparse (Bernhoft & Carstensen, 2008). With respect to choosing a time gap between two vehicles for crossing a road, studies have revealed inconsistent results. On the one hand, a larger median time gap was chosen by elderly pedestrians compared to younger age groups when crossing a simulated one-way street (Lobjois & Cavallo, 2007, 2009). On the other hand, pedestrians aged 72 to 85 years were found to adopt smaller safety margins and to make more decisions that led to collisions than did younger groups of pedestrians. These age-related difficulties were even more evident when vehicles approached rapidly or in the far lane (Dommes et al., 2014). With respect to start-up time which corresponds to the time between the decision to cross a road and the first step into the street slightly longer times have been observed for older pedestrians waiting for a green walk sign than for younger ones (Knoblauch, Pietrucha, Itzburg, 1996). When crossing the road, it was shown that older pedestrians overestimate their own walking speed and have difficulties adapting it according to the actual traffic conditions (Dommes & Cavallo, 2011; Dommes, Cavallo, Oxley, 2013).

5.4 Conclusion

In this chapter the behaviour of elderly road users in traffic has been investigated. Several international researches and specific query on in-depth database were used, but the amount of data is still low and specific for some countries.

As **car occupants**, the elderly drivers are less prone to show risky behaviour; they drive less often and drive shorter distances than their younger counterparts, avoid driving under bad weather conditions and driving at night time. Moreover seniors had rarely or never driven faster than the speed limit allowed inside built-up areas. Accidentology data have shown that seniors sit predominantly in the front seating position (drivers or passengers): the male elderly is used to drive the car; female are more relevant as co-drivers. They use seat belts more often than any other age group, in particular they very often worn a seat belt as a passenger in the front of the car and nearly always worn a seat belt in the back of the car.

However, senior drivers are used to have more accidents because of distractions, traffic signals violation and driving errors (such as zig-zag driving or insufficient safety distance) than younger drivers. This fact is probably because of poor reflexes and a lack of attention. The accident risk might be overrated due to different biases such as the higher vulnerability (and thus the probability of getting seriously injured) with increasing age, higher chance of getting accident reported by the police and because senior drivers are overrepresented in the group of low mileage drivers (who are more often exposed to complex situations).

The rate of collisions with other vehicles that turn into or cross a road among all accidents seems to increase with age and seems to be the most relevant accident category for senior drivers.

As **cyclists**, the main violations of traffic rules are due to riding bicycle on sidewalk and this could be seen as a way to self-regulate their driving by avoiding certain situations. Older cyclists barely receive warnings due to talking on the phone, riding in the dark without lights, and alcohol (in accordance with self-reported data on behaviour). Similar as car drivers, the lack of attention and traffic signal violation is higher cause of accidents for senior drivers than for younger ones.

The proportion of elderly who reported to wear a helmet and good visible clothing when riding a bike is low in Germany compared to Spain. Of all cyclist fatalities, 57% were killed inside urban areas; but it is worth of notice that the 42% of all killed cyclists were 65 years or older.

Data analysis showed that the cyclist fatality rate increases with age (mainly due to increased frailty).

As **pedestrian** elderly is more involved in accidents. The pedestrian fatality rate is especially high for seniors of 75 years and older (mainly due to increased frailty). European research conducted in 2014 revealed that around 44% of all killed pedestrians were 65 years or older. Accidents occurred mostly in urban areas (mainly on intersections). Frequently pedestrian accidents occurred when they were crossing followed by when they were walking on the road as a result of falling.

Among elderly pedestrians a decrease in walking speed and acceleration capacity is registered; actually they spend more time looking at the ground when crossing road and, in general, prefer using pedestrian crosswalks and intersections with signals. It is common that they overestimate own walking speed, and show difficulties adapting walking speed according to the actual traffic conditions.

Moreover, it has been seen than senior pedestrian use to have more accidents than youngers when they are improperly crossing. In accordance with mentioned above, their physical capacities are poorer. Nevertheless the behaviour of older pedestrians in traffic has not yet been studied extensively. Future research activities need to provide more information on among others road crossing attitudes of elderly pedestrians, compliance with traffic rules, self-regulation and the engagement in potentially distracting activities.

6. Final remarks

Nowadays, the elderly become more mobile due to their increased longevity and better health. Currently, older road users travel more than their comparable age groups 20-25 years ago. The everyday trip rates are higher and activities outside home become more common (Banister & Bowling, 2004; Dejoux, Bussière, Madre, Armoogum, 2010; Hjorthol, Levin, Sirén, 2010; Rosenbloom, 2001; Buehler & Nobis, 2010).

It is desirable that all older road users are able to use as many different modes of transport as possible. Widening the range of mode selection for older road users and preventing older road users from changing into or maintaining in a profile with low activity levels and limited mobility.

On average, the car is the most preferred means of transportation by older road users, after walking. In Europe approximately half of all older road users' trips are made by car. Furthermore, walking is also an important transportation mode in Europe since 30-50% of the older road users' trips are made on foot. Cycling seems to be of minor significance as a transport mode for the elderly. The choice of a transport mode by older road users mainly depends on the availability of a car, gender, income, health, household structure and residence. Women are less dependent on the car and rely more on walking and public transport than men who have a strong connection to the private car. Walking and public transport services are more dominant in urban areas while the private car is more often used in the countryside (Polders et al., 2015).

Age brings about changes to skills central to the driving task, but there is good evidence to support the notion that older drivers are adept at compensating for their performance decline.

Supporting this position, literature and database analyses carried out, indicates that senior drivers and cyclists are aware of weather or darkness when they have to drive. However they use to be less attentive and they have a lack of reflexes that make senior drivers and cyclists tend to have more accidents because of distractions and violation of traffic signals. As pedestrians, seniors, are more prone to suffer accidents when crossing or because of falling down. Moreover, elderly victims of traffic accident have higher risk severe or fatal accidents as they have a higher risk of severe injuries than the younger group because of physical fragility.

The 'silver' economy (for older car users and purchasers) is crucial for carmakers as well, because the demographic change towards an older population is currently being reflected in the new-car market. Studies from the US have shown that the older drivers are used to buy cars designed with advanced safety systems such as passive protection, but also active systems, to reduce the human interaction during driving and compensate any physical or cognitive deficit in ability (Gales, 2013).

It is relevant to underline that new vehicles are becoming easier to drive (due to features such as steering assistance, lighter gear changes and emergency brake assist). This makes it easier for drivers with physical limitations to operate a vehicle safely. For elderly people, due to a higher proportion of injuries to thorax among older drivers than younger car occupants, injury severity might be reduced by improvements of restraint systems.

6.1 RELEVANT FINDINGS TO OTHER SPECIFIC TASKS IN SENIORS

The results presented include various information that can be further used within the SENIORS project. Most relevant facts are summarized in the following subsections.

- Older road users travel more than their comparable age group a generation ago.
- Seniors realize quite the same number of daily movements per person as the overall population with a same trend followed by men and women.
- Seniors move every day with different transport modes; the time of travel is about one hour long; trips are short and happen mainly in urban area.
- The car is the most preferred means of transport by older road users, after walking. The car is typically used for longer distances and time. Actually rate of elderly driver's license owners has risen over the years.
- According to gender women spend much time by public transport while men spend more time with motorized individual transport (car, motorbike, e-bikes/pedelec).
- Older drivers are adapt at compensating for their performance decline and often engage in self-limiting practices such as stopping driving at night or in heavy traffic conditions.
- Data analysis shows that the elderly fatality rate increases with age (mainly due to increased frailty). This happens for all road users: car occupants, cyclist and pedestrian.
- Due to frequent wearing seatbelt and fragility, serious thorax injury, also at slow speed, are reported.
- ADAS could help to go beyond physical and visual deficit of the elderly.

As car occupants:

- The elderly drivers are less prone to show risky behaviour; they drive less often and drive shorter distances than their younger counterparts, avoid driving under bad weather conditions and driving at night time.
- Seniors had rarely or never driven faster than the speed limit allowed inside build-up areas.
- Male elderly is used to drive the car, while the female are more relevant as co-driver. Very low is the percentage of elderly in the back of the car.
- Elderly people use seat belts more often than any other age group, in particular they always worn a seat belt as a passenger in the front of the car and always worn a seat belt in the back of the car.
- The researches in several countries have shown that over 50% adjusted the seat belt height for better fit or comfort.
- Seat accessories, such as base cushions are used, especially when seniors aren't able to adjust the seatbelt. No accidentology data, except US databases

are available on these factors because the variables aren't coded in EU databases.

- Investigations conducted reveal that most accidents of seniors happen on urban roads (seniors travel more on local roads than freeways and multi-lane divided roadways), mostly rear-end and angle-crashes; and the most frequent driving errors among elderly are disregard of the right of way and errors when turning, reversing, entering the flow of traffic or starting off the edge of the road.

As cyclists

- Considering that the laws are different in the countries there isn't a general indicator about the usage of helmet. The proportion of elderly who report to wear helmet and visible clothing when riding bike is low in Germany compared with Spain.
- The elderly violate traffic rules mostly riding bicycle on sidewalk. No violations due to talking on the phone, riding in the dark without lights, or alcohol.
- The accidentology rate in Europe has shown that the 42% of all killed cyclists are 65 years or older and the accidents occurred especially inside urban areas.
- Mostly single-bicycle crashes, followed by collisions with cars and other cyclists are the main accident scenarios; the most frequent causes of accidents are poor surface, losing balance, not seeing obstacle.

As pedestrians

- Elderly pedestrians show a decrease in walking speed and acceleration capacity and they spend more time looking at the ground when crossing road.
- Elderly pedestrians prefer using pedestrian crosswalks and intersections with signals. Accidents occurred mostly in urban area (mainly on T-junctions and intersections).
- Frequently pedestrian accidents occurred when they were crossing followed by when they were walking on the road as a result of falling.
- It is common that they overestimate own walking speed, and show difficulties adapting walking speed according to the actual traffic conditions. Future research activities need to yield in-depth information on the locations (and involved parties) of both traffic crashes and falls of senior pedestrians as well as on the types of injuries which result from the accidents.

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